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QUARTERLY JOURNAL

OF

MICROSCOPICAL SCIENCE:

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the fourth form was of a light pinkish red, and did not contain purple pentacrinin at all.

The specimens of Pentacrinus obtained off the Ke islands, when in the fresh condition, had their stems almost white, and their crowns of a light yellow or light reddish orange, showing no purple coloration at all; and those dredged off Panglao and Signijor islands were almost colourless; nevertheless, when placed in alcohol, they yielded a solution which was deeply coloured of a sap green, and which, when acidified, became of the usual deep pink of pentacrinin. The pentacrinin was thus in these examples, though present in great abundance, entirely masked. It is possible that these Pentacrini would have shown an alkaline reaction in the fresh condition. Unfortunately the test was not made. The pentacrinin would be far less visible in the green alkaline condition.

Red pentacrinin.—The species of Pentacrinus obtained off the Meangis islands, which was of a light pinkish-red colour, gave a simple light-red solution in absolute alcohol. This solution, when very intense, absorbed all the spectrum except a band of light between E and B (Pl. I, fig. 6 *a*). When the solution was weaker it showed a single broad band in the region of E, *b* and F, with some absorption of the ends of the spectrum (Pl. I, fig. 6 *b*). Addition of ammonia reduced the brightness of the colour of the solution, and when added in quantity caused the absorption band to disappear. It did not render the solution at all green. Hence this one species was devoid of pentacrinin, and contained an entirely different colouring matter.

Antedonin.—The various species of Antedon appear to be usually either of a rose colour or of an orange or yellow, running into a yellow brown or of a dark purple. Both the rose or red and yellow colouring matters are freely soluble in alcohol and usually in fresh water. The coloured solutions obtained from a large number of such species dredged by the Challenger were examined, but none of them yielded a characteristic absorption spectrum showing bands. The European species have been similarly found to yield a colouring matter free from bands. In the case of *Antedon rosaceus* all the spectrum but the red is absorbed. I found a purple species occurring at Suez to yield a similar spectrum.

By dredging in from 8 to 12 fathoms in the channel between Somerset and Albany Island, at Cape York, Australia, an Antedon was obtained in abundance which was of a dark purple colour. The colouring matter is insoluble in glycerine, soluble to a large extent in fresh water, and abundantly

soluble in weak spirit, and gives an intense fuchsin-coloured solution. This, when compared with that obtained from a deep sea Holothurian found to contain the same colouring matter (*v. inf.*), is seen to be much redder, but it becomes pinker as diluted with alcohol, and at last quite pink and indistinguishable to the naked eye from that of the Holothurian. The solution when of moderate strength gives a spectrum consisting of three well-defined absorption bands (Pl. I, fig. 9 *a*). On using a very weak solution and gradually strengthening it the least refrangible band, as being the most intense, appears first, and is visible in solutions which appear very slightly tinted indeed to the unassisted eye. The other two bands appear together. The middle band is at first darkest about E. The most refrangible band, which is much less dark than the middle one, is of uniform intensity. Neither the red nor violet ends of the spectrum are much absorbed.

When the solution is very strong all three bands become intense; the violet disappears and all the light, except the red and yellow, becomes very faint. The bands remain as before, except that the middle band now appears of uniform intensity throughout. When the solution is rendered stronger still, the least refrangible band extends gradually up towards D, and the whole of the spectrum becomes absorbed, except a band of light, consisting of red with a little yellow (Pl. I, fig. 2 *b*).

On the addition of hydrochloric acid to the alcoholic solution the colour changes to an orange, and the spectrum now consists of two bands (Pl. I, fig. 7 *c*), one lying to the red side of E, the other to the violet side of *b* and extending to F. These bands are in weak solutions separated by an interval of light. In very intense solutions the bands are joined by the absorption at the violet end of the spectrum, and the spectrum consists of a simple band of red, yellow, and green light (Pl. II, fig. 9 *c*). In solutions of intermediate strength the two bands are connected together by a clouding interrupted by lighter streaks, whilst the more refrangible band is dark just about the region of F, and has its main darkest mass separated from this dark narrow streak at F by a lighter interval.

On the alcoholic solution being rendered alkaline by addition of ammonia, it changes its colour to a deep violet, and a flocculent purple precipitate is formed in it, which can readily be separated by filtration. The precipitate when dried appears as a violet amorphous powder, which is insoluble in alcohol and oil of cloves, and can thus be

rendered transparent and mounted in Canada balsam as adhering to the filtering paper. This precipitate when thus dried yields the same spectrum as it does when suspended in the solution. The spectrum consists of two bands as figured (Pl. II, fig. 7 *d*).

The dried precipitate is insoluble in water, ether, and alcohol, but soluble in acidified alcohol, and then gives the original acid spectrum (Pl. I, fig. 7 *c*), and when this solution is carefully neutralised the original three-banded spectrum returns, but I obtained it only faintly. Though a very large quantity of precipitate was removed by ammonia from a strong and original alcoholic solution, the solution still remained of a vivid colour and gave its three bands. It was only after continued addition of ammonia that the whole of the colouring matter was precipitated.

The colouring matter appears to require a proportionately increased quantity of ammonia to precipitate it, as the solution becomes weaker. Both the dried colouring matter and the alcoholic solution have maintained their colour and properties unimpaired after a lapse of two years.

Hymenaster.—Several new species of this deep-sea genus of Sir C. Wyville Thomson were obtained by the Challenger from deep water. They are of a brilliant scarlet colour when fresh, and the colour is rapidly discharged in alcohol. The resulting deeply coloured solution yields, however, no absorption bands, but a spectrum in which all the light except the red is sharply cut off. Many other brightly coloured star-fish were examined, but with a similar result.

Hoplacanthinin.—Several specimens of an echinoid of the genus Hoplacanthus were obtained by H.M.S. Challenger. They are of a dark madder colour. Observations were made on specimens obtained in latitude 6°48′ N., longitude 122°25′ E. from 800 fathoms, October 23rd, 1874. The colouring matter is freely soluble in alcohol, yielding a madder-coloured solution, which shows in the spectrum two not very sharply defined bands (Pl. II, fig. 8). The colouring matter became precipitated in the alcoholic solution when left to stand in about twelve hours. The absorption bands could not be obtained from the precipitate.

Antedonin from Holothurian.—On Feb. 26th, 1874, in latitude 62°26′, longitude 95°44′ E., in the extreme south of the South Indian Ocean, a large Holothurian, with a gelatinous test, was dredged from 1975 fathoms. The holothurian was about ten inches long, and three or six broad. The animal was of a uniform dark purple colour. The colouring matter present appeared to be identical with that obtained from the Antedon

dredged at Cape York. It was not obtained in so intense a solution as from the Antedon, the coagulation of the gelatinous matter in alcohol no doubt preventing so free a solution. The spectra yielded by the colouring matter are figured (Pl. II, fig. 9, *a*, *b*, *c*, *d*, *e*). In some unimportant respects a difference between the colouring matter of this Holothurian and that from the Antedon was observed. The alcoholic solution of the Holothurian colouring matter absorbs the red and violet ends of the spectrum more than that of the Antedon (Pl. II, fig. 9 *b*), and when acidified with hydrochloric acid in strong solution shows a greater extension of its less refrangible band towards D than does the similar solution from Antedon (Pl. II, fig. 9 *d*). In weak solutions, however, it gives two bands (Pl. II, fig. 9 *c*) coincident with those of the Antedon. It is probable that the slight difference observed is only due to the turbidity of the solution of colouring matter from the Holothurian, which is caused by the gelatinous nature of the animal. Specimens of the same species of Holothurian, or very similar forms, were several times dredged by the Challenger in deep water in various parts of the world, and they were found to be similarly coloured.

Worms.

Land planarians.—At Parramatta, near Sydney, New South Wales, two large species of Rynchodemus are tolerably common, one of which is of a uniform Prussian blue colour, whilst the other is of a uniform red. In the blue species the blue pigment is confined to the superficial structures, and is most abundant in the cells containing the rod-like bodies. It is insoluble in alcohol. It changes when acidified with dilute hydrochloric acid to a red, and is soluble in acidified alcohol. Neither the red nor the blue pigments yield absorption bands in the spectrum. The pigment can be rendered blue or red by being made alkaline or acid any number of times.

It was thought possible that the red species would be found to contain the same pigment as the blue one in the acid condition, since the two species are exactly alike in form and occur together, but such was found not to be the case. The red form contains red pigment which does not turn blue on being rendered alkaline, and which is insoluble in acidified alcohol.

Eteone.—A species of Eteone was obtained from 1127 fathoms, lat. 41·57° N., long. 9·42°, which had a bright

green pigment in its appendages as is the case in allied shallow water forms as Phyllodice.[1]

Sabella.—A Sabella obtained from 600 fathoms contained chlorocruorin as do shallow-water Sabellæ.[2]

Sagitta.—Several species of Sagitta were obtained, some being very large. The large ones contained an abundant red oily pigment soluble in alcohol, which absorbs all the spectrum but the red and yellow (Pl. IV, fig. 1).

Crustacea.

Crustaceorubrin.—Many deep-sea Decapods of various forms are coloured of an intense scarlet. This is the case both with Schizopods, such as Gnathophausia and Petalophthalmos (Suhm), and in the Peneids and Caridids, which are excessively abundant in deep water. The oily red colouring matter of these Crustacea is soluble in alcohol, and is in time entirely removed by spirit from specimens preserved in it. The resulting red solution gives a single broad absorption band in the green and blue (Pl. II, fig. 11). Addition of hydrochloric acid or of ammonia to the solution does not alter the spectrum. A similar red solution yielding the same spectrum is formed when large quantities of red pigmented surface Entomostraca are preserved in spirit. The colouring matter seems to be identical in the two cases.

Pandarus.—A red colouring matter, probably the same as the above, was detected with the microspectroscope in a Pandarus infesting a Carcharias brachiurus, which was caught off the Kermadec Islands. So small a quantity of the colouring matter was present that the absorption band obtained was faint and not nearly so extensive as that shown by intense solutions from the red decapods. It is probable, however, that the colouring matter is the same (Pl. II, fig. 12).

Mollusca.

Aplysiopurpurin.—An Aplysia is very abundant on the shore at St. Vincent, Cape Verdes. Its habits are described by Mr. Darwin in his Journal.[3] The purple fluid emitted by this mollusc is soluble in alcohol. It yields a broad absorption band in the green and blue, consisting of a darker and a lighter portion in weak solutions (Pl. II, fig. 13 *a*), but entirely black in intense solutions. On the solution being acidified it changes to a beautiful violet, and then

[1] E. R. Lankester, 'Journal of Anatomy and Physiology,' vol. iv, p. 121.
[2] Ibid., 'Quarterly Journal Microscopical Science,' Nov., 1867.
[3] 'Darwin's Journal,' 2nd edition, p. 6.

yields the spectrum shown (Pl. II, fig. 13 *b*). The ends of the spectrum are very little absorbed by either of the two solutions. The colouring matters are evanescent and soon fade.

In Bronn's 'Klassen und Ordnungen des Thierreichs'[1] it is stated that the coloured fluid of Aplysia is, when fresh, purple red. Hydrochloric acid in small quantities intensifies the purple colour of the fluid, in larger, changes it to blue. Huschke says the fluid contains iodine, but the purple colour cannot be derived from this.

An Italian chemist has recently stated that an anilin base is present in Aplysia.

Doris.—A Doris or example of a closely allied genus obtained in lat. 0°33′ S., long. 151°34′ W., from 2425 fathoms, September 6th, 1875, had the surface of its foot coloured of a dark purple, whilst the remainder of the body surface was devoid of such pigment. The purple colouring matter was found to be soluble in alcohol acidified with hydrochloric acid, and both when fresh and in solution gave a spectrum showing two well-marked absorption bands (Pl. II, fig. 14) which resemble those obtained from the acidified solution of the colouring matter of Aplysia.

In the Doris, however, the spectrum of the fresh colouring matter is identical with that of the acidified solution. It is thus possible that the colouring matter exists in the animal naturally in the acid form.

Ianthinin.—Some large specimens of Ianthina were procured on the surface of the North Atlantic, on June 20th, 1873, and afforded an opportunity for the examination of the well-known purple-coloured fluid emitted by those animals, and for corroborating some observations made previously during the voyage.

The colouring matter in question is soluble in spirit, but apparently only to a limited extent, since, if after a number of Ianthinas have remained for a day or so in spirit, the coloured spirit be poured off and fresh spirit substituted, the colouring matter is seen to be shed out, and in a dense cloud, and this spirit rapidly becomes as intensely coloured as the preceding.

The spirit solution is of a pale pinkish-blue colour when viewed by directly transmitted light, but when held so that the light reaches the eye from it obliquely it displays a most brilliant red fluorescence, in this matter resembling greatly Æsculin, which is also blue by transmitted light.

When examined spectroscopically by transmitted light

[1] Bd. III, p. 756.

the alcoholic solution shows three absorption bands (Pl. II, fig. 15 *a*). One, an extremely intense band with well-defined edges, extends from a little beyond the less refrangible side of D to about one third of the distance between D and E. The next band is faint, not so broad as the preceding, and situate a little to the less refrangible side of E. The third band is also faint, but rather darker than the last described; it extends from F towards the red, and shades gradually off towards its red edge. The position of the bands is given in the figure. The least refrangible band is so well marked that it is easily seen with a weak solution; but the two others, being fainter, require strong solution used in considerable thickness, and with not too high a dispersion, to come out well. The red end of the spectrum is cut off as far as almost up to B; the blue end is visible just into the violet.

If a drop of hydrochloric acid be added to the spirit solution the colour changes at once to a clear pale blue, and the spectrum changes to a single band (Pl. II, fig. 15 *b*), dark in the centre, and shading off at the edges, which band is placed nearer the red than the dark band of the alkaline solution, and overlaps the D line towards the green by about one third of its breadth. The original colour and spectrum are restored on the fluid being again rendered alkaline with ammonia.

If an ianthina be pricked and made to discharge its purple into a test-tube containing glycerine the colouring matter is dissolved, and a solution obtained which has a deep violet colour, and gives the three bands like the spirit solution.

If the purple be treated in the same manner with ether a coloured solution is obtained, resembling exactly the spirit one in appearance, fluorescence, and spectrum. The ether does not become very highly tinged, but leaves a coloured residue, which, after the ether is poured off, may be dissolved in absolute alcohol. A blueish solution showing one absorption band is the result.

If the fresh purple fluid be treated with acidified ether a most brilliant dark blue solution is obtained, which is not fluorescent, and which gives the spectrum shown (Pl. II, fig. 15 *c*).

No method by which the colouring matter, which may be called Ianthinin, could be preserved was discovered. All the various solutions mentioned above faded in the course of a week or two, and the ethereal solutions even more rapidly.

Phosphorescence.—The phosphorescent light emitted by three genera of deep-sea *Alcyonarians* was examined spec-

troscopically. The spectra are figured in the accompanying woodcut.

Fig. 1 represents the spectrum obtained from a species of *Mopsea* dredged from 600 fathoms. The light, as usual, was emitted very vividly on the animals being put into fresh water, but, as usual, soon exhausted under the influence of this stimulus.

Fig. 2 represents the spectrum yielded by a *Virgularian* obtained from 1090 fathoms. The yellow was in this case especially brilliant. Portions of phosphorescent tissue were readily detached from the specimen. The light was greatly increased on the tissue being squeezed or rubbed.

Fig. 3 gives the spectrum obtained from an *Umbellula* from 2500 fathoms. Here also the light was greatly increased by the action of fresh water. The specimen was placed first in fresh water, then in salt water, and finally in spirit. Very vivid light was emitted as it came in contact with the spirit. The whole stem was phosphorescent.

It will be remarked that the light emitted by the *Umbellula* consists solely of yellow and green light, whilst both of the other *Alcyonarians* produce a considerable quantity of red light. The *Virgularian* gives out more red light than the *Mopsea;* the *Mopsea,* on the other hand, making up for the deficiency by showing more green.

The effects of various forms of stimulus on the amount of light produced seems in these deep-sea *Alcyonarians* to agree with those to be observed in the case of similar shallow-water forms.

General Remarks.

My friend, Professor Lankester, in his long series of observations on animal colouring matters, published at various times,[1] seems to have been somewhat unfor-

[1] *Blue Stentorin.*—"The Colouring Matter of *Stentor cæruleus,*" by E.

tunate in not meeting with a larger number of these colouring matters yielding characteristic banded spectra. One of the most striking results of the present series of observations is the comparatively large number of animal coloured bodies yielding banded spectra which have been met with. It must, however, be remembered that in the present instance also a very large number of animal colouring matters occurring in animals of most various kinds spread over the greater part of the world have been passed in review with a very large proportion of negative results, and that the results here published represent the fruit of work extending over a period of three years and a half.

Professor Lankester in his paper on Blue Stentorin above cited[1] enumerates the few animal colouring matters known at the time of the publication of his paper to yield banded spectra. The list must now be more than doubled, and should stand thus:

Hæmoglobin (for its distribution see Lankester, 'Proc. Royal Soc,' No. 140, 1873).

Chlorocruorin (Lankester, 'Quart. Journ. Micro. Science,' Nov., 1867, 'Journal of Anat. and Physiol.,' vol. iv.)

Bonellein (Sorby, 'Quart. Journ. Micro. Science,' vol. xv, 166).

Bile-pigments and derivatives.

Chlorophylloid substances (in Spongilla fluviatilis, Sorby, 'Quart. Journ. Micro. Science,' vol. xv, p. 7).

Turacin (A. H. Church, 'Phil. Trans. S. Soc.,' 1869, p. 627).

Aphidein and allies (Sorby, 'Quart. Journ. Micro. Science,' vol. xi).

Actiniochrome, from Bunodes crassicornis (H. N. Moseley, 'Quart. Journ. Micro. Science,' vol. xiii, p. 143, 1873).

Blue stentorin (Lankester, ibid., p. 139).

Pigment of Odax and Labricthys (fish) (George Francis, of Adelaide, 'Nature,' p. 167, Dec. 30th, 1875).

Polyperythrin.

Red colouring of Cœnopsammia.

Two distinct colouring matters in Adamsia sp.

Purple pentacrinin.

Red pentacrinin.

R. Lankester, 'Quart. Journ. Microscopical Science,' Vol. XIII, new ser. See also other papers in the same Journal.

[1] Abstract of a "Report on the Spectroscopic Examination of Animal Substances," presented to the British Association at Exeter, 1869, by E. R. Lankester, 'Journal of Anatomy and Physiology,' vol. iv.

Antedonin, found in certain Holothurians as well as in Antedon.

Hoplacanthinin.

Crustaceorubrin.

Aplysiopurpurin (the same probably in Doris).

Ianthinin.

No doubt the list is capable of much furthur extension. Besides hæmoglobin, the distribution of which is so wide and yet so partial (Lankester, 'Proc. Royal Soc.,' No. 140, 1873), and bile pigments, peculiar colouring matters giving absorption spectra have now been found to exist in members of all the seven groups of the animal kingdom. Amongst Protozoa such colouring matters occurs in Infusoria and Sponges; amongst Cœlenterata they occur both in Anthozoa and Hydromedusæ, in Echinodermata in both Crinoidea, Echinoidea and Holothuroidea, but not in the Asteroidea. In Vermes, in Annelids and Gephyreans. In Arthropoda, in Crustacea and in Insecta. In Mollusks, in Gasteropods only. In Vertebrata, in four fish, three species of Odax, and one Labricthys, and twelve birds[1] of two closely allied genera. The Echinodermata and Cœlenterata appear to be the groups which are most prolific of such colouring matters.

The apparently capricious restriction of these colouring matters to certain parts only of the animals possessing them has been dwelt on by Professor Lankester (*l. c.*). In the case of hæmoglobin such instances, as its restriction to the pharyngeal muscles of certain Gasteropods, and the nerve-ganglia of *Aphrodite aculeata*, may be cited, as also its occurrence only in the muscles of the dorsal fin of Hippocampus amongst the muscles of that fish. I may add an observation of my own of a somewhat parallel case to this latter, viz. that in sharks of the genus Carcharias, of which many were caught and skinned on board the Challenger, a thin layer of muscles next the skin, and closely adherent to it, is tinged of a deep red colour with hæmoglobin, appearing like mammalian muscle, whilst all the deeper layers of muscle forming the main mass of the body are pale and almost white. In a *Carcharias brachiurus* caught off the Kermadec Islands this red layer of muscles was not more than a quarter of an inch in thickness. Mr. Lankester accounts for the presence of the hæmoglobin in the muscles of the dorsal fin of Hippocampus by the special activity of that organ, but such an explanation fails in the case of the shark,

[1] During the voyage of the Challenger I believe I saw a notice in some scientific periodical to the effect that turacin had been discovered in an Australian parroquet. I cannot find the statement again.

the skin being apparently immovable. Moreover, the structure of the skin precludes the idea of its having a respiratory function. I believe that the transparent pelagic fish Plagusia will be found, like Leptocephalus, to be devoid of hæmoglobin. I unfortunately did not test it with the spectroscope, but observed several living specimens to be devoid of red colouring under the microscope. I examined many Planarians for hæmoglobin, but did not find it in any, although it occurs in a parasitic species which I found at Suez in 1872.[1]

Besides hæmogloblin several others of the colouring matters here under consideration occur in curiously restricted regions in various animals. I have described in a former paper[2] the curious restriction of actiniochrome in specimens of *Bunódes crassicornis*, which are decolorised by the action of muddy tidal water, to the gonidial tubercles of the animal. Turacin is restricted to certain feathers and certain parts of feathers only, and in Labricthys the green pigment discovered by Mr. G. Francis is restricted to certain stripes on the body. Polyperythrin was found, as already described, to be diffused generally in the tissues of some of the Cœlenterates in which it occurs, whilst in others it is restricted to certain superficial stripes, and in one Actinia to the surfaces of the mesenteries in the interior of the animal only. In different specimens of the same species, *Flabellum variabile*, in which species it is often present in abundance, it is sometimes entirely absent, sometimes tinges the calcareous skeleton, and sometimes does not.

Pentacrinin and Antedonin seem to be widely diffused in immense quantities through the tissues of the crinoids in which they occur; and Echinoderms generally seem to be characterised by the presence of evenly diffused, abundant and readily soluble pigments.

Those colouring matters which, like those at present under consideration, absorb certain isolated areas of the visible spectrum, must be considered as more complex *as pigments* than those which merely absorb more or less of the ends of the spectrum, since in the latter case the sensation of resulting colour is produced by the action on the eye of an evenly graduated range of light of various refrangibilities, whilst in the former the scale of colours is interrupted at variously placed intervals of darkness, and a more complex mixture of residual colours ensues. By the human eye the finer complexities of colour are not distinguished, and although some

[1] H. N. Moseley, 'Nature,' vol. v, January 4th, 1872, p. 184.
[2] H. N. M., on "Actiniochrome," 'Quart. Journ. Mic. Science,' Vol. XIII, 1873, p. 143.

colours produced by absorption spectra, such as turacin, have a tint which strikes the eye at once as remarkable and peculiar, yet it is impossible to tell beforehand which colouring matters will yield absorption bands in their spectra and which will fail to do so.

It seems improbable that the eyes of other animals are more perfect as spectroscopes than our own, and hence we are at a loss for an explanation on grounds of direct benefit to the species of the existence of the peculiar complex pigment in it. That the majority of species of Antedon should have vivid colouring matters of a simple character and that few or one only should be dyed by a very complex one is a remarkable fact, and it seems only possible to say in regard to such facts that the formation of the particular pigment in the animal is accidental, *i. e.* no more to be explained than such facts as that sulphate of copper is blue.

A certain organic compound becomes formed in the animal or plant in course of evolution, either as a directly serviceable tissue-forming element or gland component, or possibly as an inert and almost excretory product. And this compound has a complex absorptive action on light. In some animals and plants the coloured compound is turned to account by natural selection,[1] increased in quantity and distributed in various ways, either for sexual adornment, concealment, or possibly in such cases as Actinia for the attraction of prey; in others it remains unused. In some instances a colouring matter may exist in an animal or group as a rudiment, having lost a sexual or other use which it had in the ancestors of the animal in question, but having persisted. No doubt this is the case with the colouring matters of many deep-sea animals. In some cases, again, a complex substance, produced by evolution for strictly physiological purposes, and happening to have a bright colour, may be turned to further advantage by some animals possessing it for beneficial external adornment. This would seem to be the case with hæmoglobin, the redness of which, considered as to the colour only, has no use in the majority of animals, and is indeed mostly concealed in utter darkness; but in some instances, as in the cock's comb and in the faces of the white races of man, is turned to account for sexual adornment. It is quite possible that in such instances as Pentacrinus the very abundant colouring matter (Pentacrinin) may have some important physiological function as yet unknown.

It is remarkable that in animals coloured by most widely different colouring matters albinism should occur in certain numbers of individuals of a species.

[1] Notably the case of chlorophyll in green plants.

When large numbers of *Flabellum variabile* were dredged by us in the Arafura Sea a considerable number[1] were always found to be entirely devoid of pigment and pure white, the corallum itself even being colourless. Similarly amongst 300 or 400 specimens of *Renilla* (*violacea ?*) which were dredged in the mouth of the La Plata, off Monte Video, one specimen was found to be of a pure white, all the remainder being of the deepest violet. In ordinary vertebrate albinos only skin pigments are affected; but in what may be regarded as albino genera, such as the fish *Leptocephalus* and in the pelagic *Plagusia*, even hæmoglobin has disappeared.

Colouring matters must have a pedigree and a developmental history which will, in some instances, be able to be traced in the same manner as that of an organ of the body or an histological tissue. A pigment thus may become developed at the root of a zoological phylum, persist in some branches, die out in others, and in some possibly reappear by heredity. The existence of Polyperythrin in both Actinozoa and Hydrozoa amongst Cœlenterates, and its very irregular but nevertheless wide-spread distribution amongst these, seems to be only explicable on such an hypothesis. It is quite possible that the tracing of zoological relations may be facilitated by the use of the spectroscope. A careful chemical examination of some of these numerous colouring matters which do not in the fresh condition yield banded spectra would, no doubt, give evidence of their being transitional to certain of the more complex colours, which latter might possibly be produced from them artificially by action of reagents.

Most Echinoderms are endowed with intense colouring matters yielding a spectrum, in which nearly all but the red or red and a little yellow is absorbed. Since some few forms in each group of the Echinoderms, except the starfish, have colouring matters yielding banded spectra, and the same colouring matter, Antedonin, occurs in so widely separated forms as Holothuria and Antedon, it is quite possible that in most cases a mixture of colouring matters masks a pigment common to many members of the group, and yielding a banded spectrum. The examination of the colouring of young animals might yield interesting results. At the same time, no doubt, many colouring matters may have had an entirely isolated formation, as in the case of Turacin, to which there seem to be no stepping-stones; and the necessary

[1] It even became a question whether the majority of specimens were not unpigmented, in which case the exhibition of pigment or chromatism—as it might be termed, in antithesis to albinism—would become the exceptional variation in the species instead of the rule.

instability of highly complex chemical substances would render the existence of any but a very imperfect phylum of pigments impossible.

A considerable number of animal colouring matters with banded spectra may be made to yield two different spectra, according as they are rendered acid or alkaline; and they exist in the animals in which they occur either in the acid or alkaline condition, as shown by the spectra. In other animals, as in the case of Antedonin in the Holothurian and the Antedon, the colouring matter has three phases, acid, alkaline, and neutral, and exists in the animals in the intermediate neutral condition.

Colouring Matters of Deep-Sea Animals.—Very little, if any, light can penetrate from the surface of the sea to depths such as 1000 or 2000 fathoms, and I believe that experiment has shown that little or no effect is produced on sensitized paper at the moderate depth of sixty fathoms. It is probably, as far as solar light is concerned, absolutely dark at depths of 1000 fathoms and upwards, and the fact that two blind decapod crustacea were dredged by us in 450 to 490 fathoms (off Sombrero, D. W. I., March 15th, 1873) seems to point to a condition of extreme darkness at much less depths. Nevertheless, several facts show that at these depths light of some kind must exist. Some deep-sea animals are entirely destitute of the eyes possessed by their shallow-water congeners, and appear, like the blind cave animals, to rely on touch alone, being provided with specially long antenna hairs, or fine rays, for the purpose of feeling. Other animals, however, living in very deep water, have enormously enlarged eyes, and hence some light must exist; and a further evidence that such must exist is the fact that several small deep-sea Lophioid fishes have the dangling lures on their heads specially developed, and apparently rendered attractive with a view to enticing their prey, as in the case of the Angler. Professor Sir C. Wyville Thomson and Dr. Carpenter have suggested that phosphorescent animals form the source of light in the deep sea. All the Alcyonarians dredged by the Challenger in deep water were found to be brilliantly phosphorescent when brought to the surface, and their phosphorescence was found to agree in its manner of exhibition with the same conditions as are observed in the case of similar shallow-water forms. There seems no reason why the animals should not emit light when living in deep water just as do their shallow-water relatives. The light emitted by phosphorescent animals is quite possibly in some instances to be regarded only as an accidental

product, and of no use to the animal, although, of course, in some instances it has been turned to account for sexual purposes, and may have other uses occasionally. There is no reason why a constant emission of light should be more beneficial than a constant emission of heat, such as takes place in our own bodies, and it is quite conceivable that animals might exist to which obscure heat-rays might be visible, and to which, therefore, men and mammals generally would appear constantly luminous.

However, be the light beneficial to them or not, it seems certain that the deep sea must be lighted here and there by greater or smaller patches of luminous Alcyonarians, with wide intervals, probably, of total darkness intervening. Very possibly the animals with eyes congregate around these sources of light.

The phosphorescent light emitted by three species of deep-sea Alcyonarians was examined with the spectroscope and found to consist of red, yellow, and green rays only. Hence, were the light in the deep sea derived from this source, in the absence of blue and violet light, only red, yellow, and green colours could be effective. No blue animals were obtained in deep water, but blue animals are not common elsewhere. It is remarkable that almost all the deep-sea shrimps and schizopods, which were obtained in very great abundance, are of an intense bright scarlet colour, differing markedly in their intensity of colour from shallow-water forms, and having apparently for some purpose developed an unusually large quantity of the same red pigment matter which colours small surface crustacea.

A brilliant green colouring matter was found in some deep-sea Annelids.

No doubt in many cases the colouring of the deep-sea animals, as in the case of the purple Holothurians, is useless and only a case of persistence. The madder colouring of some of the soft parts of the Corals may be in like case, but possibly useful for attraction of prey, being visible by the phosphorescent light. Nearly all, if not all, of the fish certainly living on the bottom in the deep sea were of a dull black or quite white and semi-transparent.

I regret much that I did not examine deep-sea fish with regard to the existence and amount of hæmoglobin to be found in them.

The same colouring matters exist in deep-sea animals which are found in shallow-water forms. Polyperythrin is found abundantly in surface-swimming Rhizostomæ and in deep-sea Corals and Actiniæ. Antedonin occurs in a shallow water

(nine fathoms) Antedon at Cape York and in a Holothurian found in 1975 fathoms near the Antarctic Sea. No doubt in many instances in the case of deep-sea possessors of these pigments, the pigments from being in the dark never exercise their peculiar complex action on light during the whole life of the animal, but remain in darkness, never showing their colour, as does hæmoglobin in so many animals.

On STYLOCHUS PELAGICUS, *a new* SPECIES *of* PELAGIC PLANARIAN, *with notes on other* PELAGIC SPECIES, on the LARVAL FORMS *of* THYSANZOON, *and of a* GYMNOSOMATOUS PTEROPOD. By H. N. MOSELEY, Fellow of Exeter College, Oxford, Naturalist to the Challenger Expedition. (With Plate III.)

Stylochus pelagicus, a new Pelagic Planarian.

DARWIN, in 'Ann. and Mag. Nat. Hist.,' xiv, 1844, p. 241, 251, pl. v, fig. 1, described and figured a Planarian, which he found living free on the surface of the ocean, in lat. 5° S., long. 33° W. He named this Planarian *Planaria Oceanica.* The Planarian is referred to the genus Eurylepta Hempa. and Ehrenberg, by Diesing, 'Syst. Helminthum,' vol. 1, p. 211, since it agrees with the characters of that genus, having a distinct head with frontal tentacles. Two oceanic species of Stylochus,[1] *S. Mertensi* and *S. pellucidus* (Diesing), were described by Mertens, Mem. de l'Acad. Imp. des Sciences de St. Petersburg, 6 ser. sci. 'Math. Phys. et Nat.' II, 13 tab. I, figs. 4-6. Stylochus Mertensi inhabits the seaweed of the Sargasso sea. It was found by Mertens in the Atlantic between lat. 21°—35° N., and long. 36°—38° W. The species was found by us in the Challenger in abundance on Sargassum bacciferum, wherever we gathered the weed for examination. Like the crabs Lupea and Nautilograpsus, Scyllæa pelagica, the little fish Antennarius and almost all the inhabitants of the gulf weed, it has a protective resemblance in colour to the seaweed. With S. Mertensi occurred a second species of *Stylochus*, which was colourless and pellucid, and which, doubtless, was *Stylochus pellucidus.* In it a series of eyespots occur on the tentacles disposed in a single row reaching from the base to the top anteriorly.

Some notes were made on the anatomy of both these *Planarians* in the fresh state, and specimens were preserved for further examination, but the bottle containing them

[1] = Gnesioceros pellucidus and Mertensi Diesing Revision der turbellarien, 'Sitz. Acad. Wiss.,' Wien, 1861.

unfortunately was broken during heavy weather and they perished. Several specimens of a beautifully transparent Planarian were obtained at night with the surface net on August 14th, 1873, on the voyage from St. Jago, Cape Verdes, to St. Paul's Rocks in lat. 9° 21′ N. long. 18° 25′ W., and again on Aug. 19th, in lat. 5° 48′ N., long. 14° 20′ W. The sea on each occasion was highly phosphorescent, and the towing net was perfectly crammed with various surface animals. Phillirhoe, Salpæ, Megalopa, Squillerictheus, Phyllosoma, together with specimens of Cranchia, Halobates and Plagusia.

The Planarian is certainly very different in structure from Mr. Darwin's *Eurylepta Oceanica,* though it resembles it closely in habits and mode of life. From *Stylochus pellucidus,* it differs in the external characters of general outline and distribution of the eyes, and far more importantly in the structure of the generative organs.

The present oceanic form is placed in the genus Stylochus on account of the position of the tentacles. In the arrangement of the generative organs it approaches Leptoplana. The classification of Planarians will necessarily undergo great modification when the anatomical structure of a larger number of forms has been accurately investigated.

Description of *Stylochus pelagicus* (sp. n., H.N.M.).

Body flat elliptical, slightly narrower posteriorly, with a sinuous margin. Pellucid white in colour; mouth central, elliptical multilobate; a pair of dorsal tentacles; eyespots disposed in a pair of rings round the bases of the tentacles, and in two pairs of patches in front and behind the nervous ganglia.

Length 7·5 mm.; breadth 4·5 mm.

Free swimming in lat. 9° 21′ N., long. 18° 25′ W., and in lat. 5° 48′ N., long. 14° 20′ W. Although the towing net has been constantly in use during the voyage, this free swimming *Planarian* has only been obtained on the two occasions mentioned above, and then only in small numbers. The animals are extremely lively and swim quickly by means of a rapid sinuous motion of the thin lateral margins of the body. They also crawl over objects in the same way as ordinary shore *Planarians,* and are also like these in their extreme voracity, fastening immediately on any dead animals placed in the glass with them.

atomy.—The exsertile pharynx is oval in outline, and nts the usual multilobed appearance when contracted its sheath, Pl. III, fig. 9. The opening on the under ce of the body, by which the sheath communicates with

the exterior and by which the pharynx is extruded is nearly central in position. The intestine presents the usual multi-ramified arrangement, there being eight pairs of primary branches and one anterior median, which as usual passes over the cephalic ganglia and divides into three secondary branches. There is no anastomosis between any of the branches, not even between the most posterior pair, although each member of this pair gives off a short transverse branch directed inwards towards the middle line.

The cephalic ganglia are large and distinct, of the same form as in *Leptoplana tremellaris,* and of similar structure, the transverse commisural fibres being very well defined; the main nerve trunks are distributed in the usual manner, a pair of especially stout ones going to supply the posterior part of the body.

The eye spots, which are intensely black, are disposed in two pairs of groups situate in front and behind the ganglia respectively (Plate III, fig. 10), the anterior group being the largest, and in a pair of rings which encircle the bases of the tentacles. The tentacles have no eyes on their tips or sides; they are situate just in front of the junction of the anterior with the median third of the body. The water vascular system is extremely well seen, the fine peripheral translucent network being clearly defined when the animal is viewed by transmitted light. I could distinguish no openings of the system to the exterior.

The generative organs occupy an elongate space situate immediately behind the mouth (Plate III, fig. 9). The male organs consist of testis, vesicula seminalis, prostate and penis (Plate III, fig. 11). The testes are narrow and tortuous in outline, and commencing on each side at the level of the hinder margin of the sheath of the pharynx, come backwards as far as the anterior generative opening. The vasa deferentia pass almost transversely inwards, presenting at their commencement a sudden but short twist upwards, forming a small loop. This loop at the commencement of the vasa deferentia is present in very many *Planarians*, and persist even in the *Landplanarians Bipalium* and *Rynchodemus*. The vasa deferentia open into a mesially placed ovoid vesicula seminalis, beneath which is an ovoid glandular cavity, from which proceeds a wide strongly muscular duct, tortuous in its course in the retracted condition of the penis, and which terminates in the cavity of that organ.

The penis itself as seen in the retracted condition and as figured in Plate III, fig. 11, has the shape of a cone with a truncated apex. It is contained in a spacious flask-shaped

cavity or sheath with a strongly muscular wall, by contraction of which the organ is protruded, and which is in connection above with the sheath of the pharynx. Branched retractor muscular fibres are attached to the penis, taking origin from the sheath walls. The penis consists of a cavity with a muscular wall and a thick lining of horny prickles, which are, of course, on the exterior when the organ is protruded. This horny layer does not readily transmit light, hence the area occupied by it appears dark in the drawing. The cavity of the penis leads by a tortuous canal, which lies over the uterus for some distance to the anterior generative opening.

The female organs consist of a uterus, ovaries, oviducts, and albuminiparous glands.

The uterus is an ovoid chamber, with muscular walls, situate just posteriorly to the penis sheath. It opens by an oval aperture towards its posterior part. This aperture may be seen to gape widely open and again contract from time to to time as the animal is under observation in the living state. The ova are dispersed over the central region of the body, round the pharynx and ganglia, as shown in fig. 9, as in *Leptoplana tremellaris*, and other forms. Stretching up on either side of the sheath of the mouth and that of the penis from the direction of the uterus are a pair of organs, which cross the vasa deferentia on their dorsal aspect. These organs consist of a series of cells or sacs with well-defined walls filled with ova. They evidently correspond to the long tubular organs in *Leptoplana teremellaris*, which is called uterus by Keferstein ('Beiträge zur Anatomie und Entwicklungsgeschichte einiger Seeplanarien Abhandlungen der k. gessellschaft der Wiss zu Göttingen,' 1868, p. 27). The organ corresponding in *Leptoplana* to what is here termed uterus is called by Keferstein "Weibliche Geschlechts Atrium." This organ is, however, certainly the homologue of a corresponding mesially placed musclar organ in *Bipalium*, which is connected by long and slender ducts, with an ovary situate far off in the head. In Bipalium the organ could hardly be termed anything else but uterus; it receives here as in *Stylochus pelagicus* and *Septoplana tremellaris* the albuminiparous glands, first described as such by Keferstein, and its function would appear to be the reception of ripe ova, and their preparation by addition of albumen and shell for extrusion, which is just the function of a uterus. The organ has been usually termed uterus by anatomists, and there would seem to be nothing to be gained by changing its name. The whole difficulty arises from the fact that ova are scattered about in

the tissue over the body, besides appearing in a riper form in the lateral organs. But these lateral organs are surely to be regarded as reservoirs to which the ova pass from the various cells as they become ripe, where they receive perhaps addition of yelk, and where they are stored until fecundation is effected. They thus correspond to the lower and central parts of the ovaries of Bipalium and other forms in which the ripe ova are to be found awaiting passage to the uterus, whilst the upper parts are filled with ova in all stages of development.

The exact mode of connection of these lateral organs with the uterus was not observed. The organs were also observed in only one specimen out of the four examined. They were not present in the one figured by means of the camera lucida, fig. 9. It is probable that the male and female elements reach maturity at different periods in each individual, and that the one specimen had the female organs in the highest activity.

A very young specimen, 3 mm. in length, was obtained. The pharynx was much larger in proportion to the body than it is in the adult, and is more cylindrical in form with fewer folds. The branches of the intestine were fully developed, as were also the cephalic ganglia and eyes. The ganglia especially being of their full size and thus appearing out of proportion to the body, as is the case in so many other animals in the young condition. And as they are figured by Keferstein in the young of *Leptoplana tremellaris* (Keferstein l. c. Taf. iii, figs. 20, 21).

Keferstein followed his young planarians only until they were 6 mm. in length. He remarks that they until then showed no trace of generative organs. In the young Stylochus the organs were not at all formed, but the area to be occupied by them was plainly defined and occupied by a mass of tissue, denser than that of the surrounding region, evidently destined to their formation.

Pelagic Planarian, sp. (?)

Two specimens of a pelagic Planaria were obtained by the towing-net in lat. 2° 55′ N., long. 124° 53′ E., about thirty-five miles west-north-west of Siao Talautse Islands, on October 20th, 1874. Both specimens were very small, measuring only about 3 mm. in length. They were evidently very young, having as yet no trace of generative organs, and the tissues not yet well defined.

The body (Plate III, fig. 5) was ovoid in form, and com-

pletely flattened. The posterior extremity narrowed to a blunt point. Tentacles were absent.

In the centre of the anterior extremity was a slight depression or pit, apparently an organ of sense, and which seemed to be used by the animal as such.

The mouth is elongate and folded, and large in proportion to the size of the body, as usual in young planarians. The ramifications of the digestive tube were already marked out, though not very distinctly. The forward prolongation of the main digestive tube passes as usual over the nervous ganglia.

The eyes were disposed in two irregular semicircles situate one on either side of the ganglia, with their convex side towards the latter. In one specimen there were twelve eye-spots on one side and eleven on the other; in the other eight on each side. A posterior group of three eyes on either side was in both of the specimens, separated from the remainder by the passage between it and them of the last branch given off by the main digestive tube before it passes over the ganglia. These groups of eyes seem to be homologous with those situate at the bases of the tentacles of Stylochus pelagicus.

The most interesting point about the present form is that the eyes appear to have definite directions which correspond exactly on the two sides of the body (see Plate III, fig. 13). In the above described posterior group of eyes this condition was especially marked, and was seen in both specimens of the animal. Here the most posterior eye looks directly forwards, the one directly anterior to it directly inwards, and the outer one of the group obliquely inwards and backwards; five of the remaining eyes look directly upwards; the others have definite directions, as may be seen in the figure. The arrangement of the most anterior eyes was not quite symmetrical. In the second specimen of the animal with but eight eyes on either side, the posterior group had nearly the same directions as in that just described. All of them showed direction towards definite points.

The specimen with twelve eyes on either side was of a uniform pale whitish colour. The other specimen had its upper surface covered with scattered, round, small, brownish pigment spots.

Both specimens were very lively, swimming by undulation of the body margin.

This planarian, from the seas of the East Indian Archipelago, being devoid of tentacles, seems to indicate another new pelagic species, which possibly should be referred to

the genus *Leptoplana*, but as only very young specimens were obtained the evidence is insufficient.

The species of *Pelagic planarian* at present known seem to be eight in number, viz.:—

Stylochus Mertensi,	Mertens.
— *pellucidus*,	ibid.
— *pelagicus*,	Mihi.
Leptoplana striata,	[Schmarda, 'Neu Wirbellose Thiere,' Th. i, 1, 17, Taf. ii, 34.
— sp. (?)	Mihi.
Stylochoplana tenera,	Stimpson, 'Prodromus Proc. Acad. Nat. Sci. Philad.,' 1857, p. 29.
Eurylepta oceanica,	Darwin.
Centrostomum gigas,	Schmarda, l. c., 17, Taf. iii, 36.

The two species of Mertens, living as they do on and amongst the Gulf-weed, are not thoroughly pelagic in their habits; but they are excellent swimmers, and are often to be found free in the region of the weed, and form a transition to the entirely pelagic species. Probably Schmarda's *Centrostomum gigas* may also be only occasionally free swimming.

Larva of Thysanozoon (Æolidiceros, Quatrefages). *The remarkable Planarian Larva of Johannes Müller.*

A planarian larva, closely resembling that described by Johannes Müller, in a paper entitled "Ueber eine eigenthumliche Wurmlarve aus der Classe der Turbellarien und aus der Familie der Planarien" ('Müller's Archiv,' 1850, pp. 485-500, Taf. xii, xiii), was found in great abundance on the sea surface at the harbour of Zamboangan Mindonao, Phillippines, on January 30th, 1875. The same larva was also obtained in the open sea on February 20th, 1875, at a point about 140 miles due north of Point d'Urville, New Guinea, but where reefs were not far distant.

The press of other work prevented much time being given to the study of these larvæ, and Johannes Müller's paper was not on board the ship. The larvæ are very difficult of observation, moving, as described by Müller, with great rapidity, and a frequent gyration of the body on the long axis.

The present figures were taken from specimens kept at rest by being squeezed under a covering glass. Hence the exact form of the body, which resembled much more closely Müller's figures, is not maintained. Two stages of the larva were observed.

In the younger stage (Pl. III, fig. 2) the body was of the ordinary flat form of Planarians, 1 mm. in length, and was provided with three short body processes on each side bearing long cilia. On the general body surface the cilia were very minute indeed. Brightly pigmented cells with oily contents were scattered sparsely over the body in the epidermis. These were coloured either burnt-sienna colour, bright pink, or yellow, recalling to mind the pigmented bodies in the retinas of birds and reptiles. The pharynx and nerve ganglia were well defined.

In the more advanced stage the head of the larva, which was 2 mm. in length, had assumed an abruptly squared form. Over the anterior and middle region of the body the pigment cells were grouped in patches in the epidermis, separated by intervals free of them, whilst towards its hinder extremity they were dispersed. The body was expanded at the region where the processes are given off, and gradually narrowed behind it. The processes were much longer than in the earlier larva. Although only three pairs of processes are here figured, a dorsal and a ventral process were also present, as in Müller's larva; but they are not shown in the figure, because it is taken from a somewhat compressed specimen. On the processes the long cilia were borne by large transparent cells with nucleus and nucleolus (fig. 3), which were nearly spherical in form, with a diameter of ·02 mm. and fine granular contents. These cells were highly contractile, and showed a constant twitching of their walls. The commencing differentiation of the digestive tract was marked out by straight elongate masses of cells, disposed in a radiating manner, and well defined by their opacity. The larva was of a dark, blackish appearance; its body mass was mainly composed of cells, such as figured in fig. 5. In the integument were abundance of rod cells. The rods are packed in the cells exactly as in a Thysanozoon occurring at Zamboangan, *i. e.* so as to form a hollow cylinder inside the cell (fig. 6). About ten rods occur in each cell. The rods (fig. 2) are somewhat oat-shaped, with a groove down the middle line of each face, so that their section is as shown in fig. 8. The pigment cells are disposed amongst the rod cells in the epidermis (fig. 4), together with a few elongate, transparent, colourless cells. The pigment cells are all provided with a nucleus, and are some spherical, some ovoid.

From the occurrence of this larva in a harbour, in abundance where a Thysanozoon was also found abundantly, from the structure of its peculiar rod bodies being identical with those of the Thysanozoon, and from its contain-

ing peculiar pigment cells, similar to those existing in that planarian, it was concluded, before Johannes Müller's paper was seen, that the larva must belong to Thysanozoon. Johannes Müller compared the rods and pigment bodies of his larva with those of *Thysanozoon Diesingii*, which occurred in abundance in the harbour of Trieste, where, as well as at Marseilles and Nizza, he found the larva. He concludes that the larva cannot belong to Thysanozoon, because, in the most advanced form in which he observed it, in which it has withdrawn its appendages, and taken the common planarian form, it has no tentacles; further, because the disposition of the eyes is not that found in Thysanozoon.

I have no doubt that my larva is closely similar to Johannes Müller's, probably that of a different species of the same genus. The only difference is that I believe that, in the youngest stage, my larva had only six appendages instead of eight. The disposition and number of the eyes agrees perfectly in both larvæ. I think that the occurrence of the larva in such very distant parts of world, associated in each instance with abundance of an adult Thysanozoon, when taken in conjunction with the presence in it of rod cells and pigment bodies characteristic of that genus, seem to point, without doubt, to its being the larva of the genus in question. It is quite possible that the arrangement of the eyes may become changed as development proceeds.

The Thysanozoon (*Æolidiceros quatrefages*) occurring at Zamboangan is a magnificent species, measuring, when expanded, as much as 10 cm. in length by 6 cm. in breadth, with the upper surface of a dark purple, and its peculiar villous tubercles tipped with white. Each of the villous processes bears at its tip a pencil of long tactile hairs. Johannes Müller figures, in connection wirh the rod bodies of *Thysanozoon Diesingii*, fine threads (l. c., Plate XIII, fig. 24), and says (l. c., p. 492): "Es gelang an Letztern den Nesselfaden zu sehen der diesen Körperchen die gleiche Bedeutung wie die Nesselorganen der Medusen und Polypen ertheilt." He adds that these threads are scarcely to be seen in the case of the rod bodies of the larvæ. I examined most carefully the rod bodies, both of the larva and of the adult Thysanozoon, and especially with a view to seeing threads, but found no trace of them; and I think Müller must have been mistaken. In a land planarian (*Rhynchodemus*), occurring at the Cape of Good Hope, I found rod cells, in which the elongate rods themselves are coiled up spirally, and from which they are projected as long, thick threads or rods on pressure being applied. I hope to describe these

cells soon in a general description, which I am preparing, of the land planarians observed by me on the voyage of H.M. ship Challenger.

Schmarda, 'Neue Wirbellose Thiere,' Leipzig, W. Engelman, 1859, p. 30, appears to have seen the larvæ of Müller at Belligramme. He describes it as having small villi budding out from it, and refers it to Thysanozoon.

Pteropod Larva.

The larvæ of some naked Pteropod (*Gymnosomata*) were frequently met with on the sea surface in the Pacific Ocean. The one figured Plate III, fig. 14, was taken with the surface net in the South Pacific, lat. 37° 29′ S., long. 8° 37′ W., on November 11th, 1875. It measured when moderately extended about 1 mm. in length. It was very lively and changed its form very much; but in the extended condition assumed that shown in the figure. The body was covered externally by a thick transparent epidermis, marked out on its outer surface into a series of polygonal areas. Three zones of cilia encircled the larva, one near the anterior extremity, the other near the posterior, and the third near the middle of the body. The two latter zones were continuous circlets of cilia, which cilia were borne on a zone of closely set ovoidal cells. The anterior zone of cilia was interrupted, the cilia springing from a series of rounded prominences arranged in a zone and separated by intervals devoid of cilia. From this zone of prominences sprung a pair of lobes (fig. 15), representing the foot. The lobes appeared almost as if they were two of the prominences enlarged and deprived of cilia. Beneath these lobes was an elongate depression, from the centre of which sprung an azygos elongate tentacular-like appendage—the Zipfelförmige Anhang of Gegenbaur.[1] The elongate depression narrowed to a point inferiorly, and at its extremity was the anus (fig. 15, x).

The larva was provided with a pair of extensile lips (fig. 15, Plate I), from between which the globular pharynx, with its radula sac already containing rudiments of teeth, could be protruded. The pharynx was provided with strong retractor muscles. A straight narrow œsophagus led down the axis of the body to the mass of light brown-coloured cells representing the digestive tract. A short rectum led obliquely up from below to the anus. A mass of large highly refractile transparent cells surrounded the mass of

[1] Gegenbaur, 'Pteropoden und Heteropoden.' Leipzig, 1855, taf. iv, figs. 7 and 8, &c.

digestive cells. These large cells are said by Gegenbaur to become converted into the skin glands. Figure 16 shows the larva as seen in optical section. In the fore part of the body a clear space intervened between the epidermis and the large cells, which closely surround the digestive tract in a complete layer.

Two pairs of ganglia were seen connected by lateral commissures. The pair of auditory sacs were very conspicuous; one of them, the left, was very much larger than the other. They contained numerous small otoliths. Strong, longitudinal, muscular bands were seen traversing the body, being especially well marked towards its hinder extremity. No ptera, suckers, nor hook sacs were found in the larvæ, and it is hardly possible that such existed, although Gegenbaur draws attention to the great difficulty which is to be encountered in detecting the completely retracted ptera in these larvæ.

The larva here described is evidently that of a Gymnosomatous pteropod. I cannot identify it exactly with any of the numerous forms described or figured by Gegenbaur, although it closely conforms to them in structure. It may possibly be the larva of a Clione. It is figured here because it seems of importance, since its anatomy was determined with considerable exactness. The appearance of the median part of the foot as two lobes instead of in a horse-shoe form seems to be remarkable, also the imparity of the otolithic sacs; but most remarkable of all is the advanced state of development of the tissues and organs in a larva in which the ptera have not yet begun to be formed. Dr. Hermann Fol, in his elaborate memoir on the development of Pteropods ('Études sur le Developpement des Mollusques, Pteropods.' Paris: C. Reinwald, 1875), pp. 150, 151, describes the asymmetrical development in the otocysts of Pteropod larvæ, and dwells on the importance of this asymmetry as affording a means of estimating the amount of asymmetry in the general growth of the two sides of the larvæ.

He refers to the observed similar asymmetry in the development of the otoliths in a large number of Cephalophora. In the Pteropod larvæ observed by him the right otolith is the larger, whereas in my larvæ the left is the larger one. Dr. Fol has never seen more than a single otolith present in each otocyst during the larval existence of Pteropods, although later on in development several small otoliths became added to the primitive large otolith in each sac. In my larvæ no larger otoliths were present, the otocysts

being filled with numerous small otolithic particles, which were in the right sac very much less numerous than in the left (Plate III, fig. 15).

NOTE *on a* METHOD *of* PREPARING *the* CORNEA. By Dr. E. KLEIN, F.R.S.

IN his studies on inflammation, Stricker ('Medizin. Jahrbücher,' 1875) uses caustic potash as a means of producing keratitis. The centre of the cornea of a kitten is touched with a pointed stick of caustic potash, and after the lapse of twenty-four to forty-eight hours—according to the required stage of inflammation—the cornea is treated with lunar caustic, and then left to stand in water acidulated with acetic acid.

Adopting this method of Stricker's, of combining the use of caustic potash with that of lunar caustic in preparing the cornea I obtained specimens which demonstrate the normal structure of this organ in an exceedingly beautiful manner. The way I followed was this: The centre of a cornea of a young kitten that had been chloralized, was touched with the tip of a stick of caustic potash; after twenty-fours hours the surface of the cornea was gently rubbed with lunar caustic once or twice, was excised after half an hour and placed in water acidulated with acetic acid. In one or two days the organ had swollen up into a thick gelatinous body, from which thin lamellæ were stripped off by means of pointed forceps and finally mounted in glycerine. The lamellæ obtained from the anterior half of the cornea—except those on the very surface—proved most instructive.

I have before me a thin lamellæ, comprising nearly the whole breadth of the organ; the preparation has been mounted over a year, and all parts are as distinct and sharp as ever. Without intending to describe minutely the appearances presented by cornea prepared in the above manner, with regard to the abnormal changes that had taken place in the structural elements of the organ—this subject I hope to discuss at another time in a special memoir—I will mention here, that the outlines of the lymph-canal system and of the corneal corpuscles lining this are very indistinct in the centre of the cornea, this part having become destroyed more or less.

By gradual transitions we are brought into an annular region

about midway between the centre and the edge of the cornea, which is the very part to which I wish to call attention in this note. In a matrix, stained faintly yellowish-brown, we find the lymph-canal system mapped out in an exceedingly distinct manner, and in it the corneal corpuscles present themselves as very conspicuous structures. As is well known (see Stricker's paper), they are arranged in the kitten in streaks or groups in which the cells are separated or rather united by linear interstitial substance—in silver preparations by a dark line; generally at the edge of these groups the corpuscles are provided with a few thick processes. At some places the streaks are so broad that they contain three, four, or even five corpuscles, arranged quite like an endothelium. In the region under consideration, *the substance of the corneal-corpuscles appears granular and of a beautiful purple-brown colour, whereas the nucleus is clear,* and contains a few dark granules, *the outlines of the lymph-canal system containing these corpuscles being at the same time very well defined.*

The beautifully tinted granular corpuscles, each with a clear oval nucleus, separated by dark lines and contained in the sharply outlined lymph-canal system, and all this embedded in a perfectly transparent matrix faintly stained yellowish-brown, is, I think, one of the prettiest and most diagrammatic of histological objects.

SCHIEFFERDECKER'S MICROTOME. By P. KIDD, B.A.

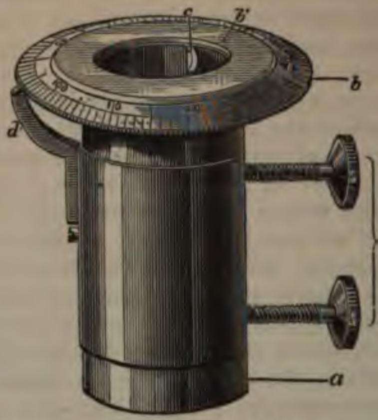
THE following instrument is a modification of Smith's microtome, devised by Dr. Schiefferdecker. It has the special advantage that thin sections of large size can be made without having recourse to embedding.

The object which is to be cut is fixed by means of a clamp (*c*) against the inner surface of the brass cylinder (*a*). This clamp is worked by two screws (*s s*).

The brass cylinder (*a*), which has a diameter of about one inch and a quarter, is fixed, and a circular plate (*b*) moves up or down on *a* by means of a screw.

The circular plate is turned round through one or two degrees after each section is made. An index (*d*) marks the number of degrees through which the circular plate is turned. The only precautions necessary in using the microtome are—

1st. To place the tissue to be cut, in absolute alcohol for a few minutes previously, so as to render it as hard as possible.



a. Brass cylinder.
b. Brass plate turning on a screw.
b'. Inner plate of glass or brass.
c. Clamp.
s. s. Screw moving *c*.
d. Index.

2nd. To draw the razor or knife quickly across the flat inner plate (*b'*), to prevent tearing the tissue.

The plate (*b'*) on which the razor rests may be either of brass or, better, of glass, as the latter is less liable to become nicked and so blunt the razor.

This microtome may be purchased of F. Maier, 9, Kramer Gasse, Strasburg. The price is £1 if the flat plate (*b'*) is made of glass, 18*s*. if it is of brass. Different sizes can be had, but the medium size here described is the most convenient for ordinary purposes.

ENGELMANN *on* CONTRACTILITY *and* DOUBLE REFRACTION. (Pflüger's 'Archiv,' Bd. XI, p. 432.) By P. KIDD, B.A.

AFTER referring to Boeck's original discovery of the phenomenon of double refraction in muscles, and to Brücke's classical memoir, Engelmann states that in spite of proofs being brought forward of the association of other forms of contractile phenomena with the presence of double refraction, *e. g.* in the muscles of certain infusoria, the results were almost all negative. In consequence, the opinion prevailed that the presence of anisotropous elements in muscle was a

curious rather than an important phenomenon. This point of view was modified when it was shown by Engelmann himself (Pflüger's 'Archiv,' Bd. 7) that contraction is exclusively connected with the double-refracting layers in striped muscle. The supposition then arose that, as a general law, contraction might be dependent on the presence of double-refracting particles, especially as the boundaries between different forms of movement in protoplasm and in muscle formerly assumed to be so sharply defined had broken down.

Moreover, it had been demonstrated that in all these cases the molecular mechanism of movement was the same in principle. But a direct empirical proof was still wanting, and the present researches were undertaken with the view of supplying this.

Two methods of investigation were adopted:

1st. An examination was made of the most various forms of contractile matter with reference to their behaviour towards polarised light.

2nd. Observations of individual forms were instituted during the course of their development with a view to discover if contractility and double refraction are always mutually associated.

1. *Muscle Substance of Hydra and Hydractinia.*—On examining a living Hydra under a microscope fitted up with crossed Nichol's prisms, the uniform stripe of muscle-fibrils between the ectoderm and endoderm appears clear provided that the long axis of the portion of the animal's body under observation lies in the plane of the field of the microscope, but appears dark when it lies in the direction of one of the planes of polarisation.

In vertical sections cut through the long axis of the body the layer separating the ectoderm and endoderm does not react to polarised light. These appearances are explained by considering these longitudinal muscle-fibrils to be double-refracting uniaxial elements, whose optic axis is parallel to the long axis of the fibrils. If we consider that these elements have a positive double refraction with reference to their long axis, the appearances which are noticed in an observation with a coloured field are also explicable. It is possible that the property of double refraction does not belong exclusively to the muscle-fibrils, but also to the homogeneous supporting lamella which also lies between ectoderm and endoderm. But in our case the extent of double refraction is too great to be ascribed exclusively to the supporting lamella. For this tissue refracts light very

feebly, and possesses clearly a very great flexibility and considerable elasticity, as may be easily proved in the tentacles of the Hydra. Consequently it is probably very rich in water; and, as a rule, the amount of water contained in organized bodies and their double refracting capacity vary inversely.

Since the double-refracting capacity of the anisotropous layer of the Hydra between the ectoderm and endoderm is very considerable, and may be estimated as not less than that of the double-refracting substance of striped muscle, it is probable that apart from the supporting lamella the muscle-fibrils of the Hydra are themselves double refracting. And this can be directly proved after maceration for a short time in perosmic acid one quarter per cent., for then the muscle-fibrils can be separated from the supporting lamella by means of needles, and still show traces of double refraction. Similar results were obtained in the case of the contractile layer between the ectoderm and endoderm of a Hydractinia. Distinct fibrils could not be distinguished in this layer.

2. *Contractile Fibres and Protoplasm of Infusoria, Zoothamnium arbuscula.*—The stalk muscles of a living uninjured specimen showed a definite fibrillation, visible with a magnifying power of 150, and refracted light tolerably strongly.

During contraction the fibrils became visibly shorter and thicker. Engelmann considers that the stalk muscles of the Zoothamnium are not semi-fluid during life, but consist of tolerably definite contractile fibrils. The bands of muscle were contained in a structureless, double-contoured, and highly refractive membrane. On one side of the muscle the membrane fitted closely, but on the other loosely, so as to give rise to a space between it and the muscle. This space was filled with a colourless substance which, at the end of the branches was quite clear, but at a greater distance from the animals became increasingly richer in very small, round, tolerably refractive granules, which at last assumed the character of rather coarsely granular protoplasm. By the movements of the muscle these granules were shifted about as if in a semi-fluid mass. No active contractility was observed in this tissue.

With polarised light the stalk muscles showed themselves to be double-refracting, the degree of double refraction being equal to that shown by the muscle of vertebrates and insects when mounted in Canada balsam, and distinctly greater than that of the leg muscles of Musca examined in the living condition in salt solution or serum. The fibrils of the

stalk muscles behaved themselves like positive, uniaxial, double-refracting elements, the optic axis being parallel to the long axis of the fibres.

Tracing the development of the Zoothamnium, Engelmann found that the formation of the stalk muscles commences regularly when the stalk is about ·4 to ·6 mm. long.

The muscle appears in the form of a flat highly refractive band, about ·014 mm. in breadth, in the axis of the stalk.

From the very earliest point of its appearance it possessed contractility as well as double refraction. At the same time the protoplasmic mass surrounding the muscle appeared in the form of a stripe of finely granular substance about ·008 mm. in breadth, lying directly on one surface of the muscle. Engelmann considers this protoplasmic granular matter to be formative material for the development of the wall of the stalk as well as of the stalk muscle. The negative results of those who had previously studied the stalk muscle seem to have depended on the exceeding thinness of the elements.

In specimens of *Carchesium polypinum*, *Vorticella nebulifera*, and *Zoothamnium aselli* it was impossible to mistake the anisotropous condition of the stalk muscle, or, indeed, the much less definite though similar appearances presented by the wall of the stalk, especially in a coloured field.

In the case of *Stentor polymorphus* and *Stentor Roeselii* the cortical layer was proved to be double refracting, but owing to the impossibility of isolating the muscle-fibrils, in the natural condition, from the protoplasm of the same layer with which they are in contact, direct proof is wanting of the double-refracting capacity of these fibrils.

In different forms of Epistilis clear evidence was obtained of double refraction in the fibril layer, which in places is so frequently so far removed from the cuticula that any mistake in consequence of the double refraction of this latter can be excluded.

3. *Cilia and Spermatozoa.*—Under favorable conditions Valentin found that cilia are double refracting. Valentin's statements relate to the ciliated cells of the respiratory mucous membrane of the marmot, of the oral cavity of the frog, of the gills of the common mussel, and in *Opalina ranarum*.

Engelmann prefers the ciliated cells of the larger Rotifera and the large cilia on the gills of bivalves.

But he found that all the different cilia behave like uniaxial, positive double-refracting elements, whose optic axis is parallel to the long axis of the cilia.

The result of a study of the development of cilia in different forms of Stentor and Epistilis showed that as soon as the cilia became visible they reacted to polarised light as strongly as they did later, and from the first they were contractile. Contractility and double refraction may be said to go hand in hand in point of development.

In the case of the spermatozoa of winter frogs Valentin noticed that double refraction could be detected in these bodies when examined in half per cent. salt solution, and it may be noted here that the non-contractile head portion of the spermatozoa possessed this peculiarity as well as the contractile tail, or indeed in a higher degree than the tail, perhaps chiefly on account of its greater thickness. But there was a remarkable difference between them—the head exhibited negative double refraction with reference to the long axis of the spermatozoon, the tail, on the contrary, positive double refraction in agreement with all other contractile elements that have been investigated up to the present time.

Positive double refraction was also observed in spermatozoa from the body-cavity of *Chætogaster vermicularis*.

4. *Contractile Protoplasm of Actinosphærium Eichhornii.*—According to Engelmann the fact that the protoplasm of Amœbæ, colourless blood-corpuscles and many vegetable cells, shows no evidence of double refraction is to be explained by the existence of this protoplasm in very thin layers and by its poorness in stable molecules, as shown by the great diminution in volume which it undergoes under the influence of reagents that abstract water.

It is also due to the fact that the contractile molecules of this protoplasm are not arranged in definite parallel axes, as in muscle-fibres, but are heaped together apparently in an irregular manner and are susceptible of a change in their position and direction. Even a weak depolarising influence might be expected in this case.

But this is not the case when the protoplasm is in layers of requisite thickness, and appears as if morphologically polarised.

Here the smallest optically active particles are arranged with their axes in definite parallel directions, as in a crystal, and their optical effects must accordingly be greater. This hypothesis is not opposed to facts; a good example of this is seen in *Actinosphærium Eichhornii* (Actinophrys). When examined in a drop of water with a magnifying power of 100 with crossed Nichol's prisms, all the rays appeared bright whose long axes made an oblique angle with both planes of polarisation; but all the rays whose long axes lay in one of the planes of polarisation appeared completely dark.

After the interposition of a gypsum plate, *i.e.* with parallel Nichol's prisms, the rays that lay diagonally appeared of a pale blue and yellow colour respectively on a dark reddish-violet ground.

The double refraction of the rays was positive with respect to their long axes.

Each protoplasmic ray behaved like a positive double-refracting uniaxial fibre whose optic axis lay parallel to the long axis of the fibre, and in general parallel to the direction of shortening.

5. *First appearance of Double Refraction and Contractility during the development of Striped Muscles-fibres.*—Valentin's researches on this point seemed to justify the following conclusions:

First. That the heart muscle of the chick shows no trace of double refraction several days after the appearance of contractility.

Second. That the double refraction of striped muscle is visible before the appearance of striation.

Engelmann, from numerous observations, denies the truth of the first conclusion.

For in the course of the second day of incubation he finds that the heart muscle is distinctly though feebly double refracting, and is positive in reference to the direction of shortening when the most highly developed muscles were about ·02 to ·03 mm. in thickness, and about twice or three times as long as this.

They consisted of spindle-shaped cells, each possessing an ellipsoidal nucleus and a nucleolus. In the perfectly fresh condition neither nucleus nor cell-boundaries were visible.

The muscle-bundles seemed to consist of a homogeneous protoplasm possessed of a tolerably high refractive power. In this protoplasm lay scattered here and there small highly refractive granules. No trace of striation was noticed either in the fresh state or after treatment with alcohol (30—60 per cent.), Müller's fluid, or perosmic acid ($\frac{1}{2}$—$1\frac{1}{2}$ per cent.) Polarised light was used as well as ordinary light, but the results were negative.

Striation appeared in the heart muscle from the third to the fourth day of incubation, but already the double refracting capacity was highly developed. Probably the origin of striation in the heart muscle depends on the fact that double refracting particles already present, but distributed uniformly in an isotropous ground substance, arrange themselves regularly in groups, viz. striæ, between which are left layers of a clear singly refracting substance.

Double refraction was also observed in voluntary muscles when contraction first appeared in them and in the case of the thigh muscles small streaks of striated substance could be distinguished at the same time on the cells. Similar facts were observed in the case of fibres of the back and abdominal muscles.

In the muscle-fibres of the tongue, back, and thigh of embryos of the white mouse, 10—12 mm. in length, the first traces of double refraction were visible, but only in isolated fibres, when already striation could be recognised.

Similar phenomena were observed in the trunk and tail muscles of tadpoles of *Rana temporaria*, though the presence of highly refractive yolk-plates rendered it somewhat difficult.

Engelmann regards it as an established fact that from the time that striation is evident double refraction is also clearly visible. Possibly in the case of the voluntary muscles of vertebrates the double-refracting particles are present from the commencement in the regular arrangement which they manifest later. This would present an analogy to the stalk muscle of Vorticella and to the vibratile cilia. In other cases it seems, as was suggested for the heart muscle, that the striation depends on a regular desposition of double refracting molecules which were previously present but were distributed uniformly in the isotropous ground substance. The uniform result of all Engelmann's observations on development is to show that no appreciable interval of time exists between the appearance of contractility and double refraction.

The following general conclusion is drawn:

"Contractility, wherever and in whatever form it may occur, is associated with the presence of double-refracting, positive, uniaxial particles, whose optic axis lies in the direction of shortening."

Attention is drawn to the agreement previously found by Engelmann to exist between contractile and non-contractile uniaxial positive tissue-elements, *e.g.* connective-tissue-fibres, cell membranes, cuticulæ, &c.

This agreement is seen in the fact that both classes mentioned tend to shorten themselves by imbibition, in the direction of their optic axes, or in other words swell up in a direction at right angles to their optic axes, much more distinctly than in a direction parallel to the same axes. This peculiarity is absent in tissue elements, otherwise very closely related to them, which do not refract light doubly, *e.g.* elastic fibres and membranes.

The Minute Structure *of the* Gills *of* Lamellibranch Mollusca. By R. Holman Peck, F.L.S., Scholar of Exeter College, Oxford. (With Plates, IV, V, VI, VII.)

The investigations of which the result is here given were undertaken at the suggestion and under the guidance of Mr. Ray Lankester, and were carried on during the past year in the Histological Laboratory of Exeter College, Oxford. Specimens of Mytilus and of Cardium were kindly procured for Mr. Lankester by Mr. Charles Stewart, the talented curator of the museum of St. Thomas' Hospital, and their investigation was commenced prior to Christmas, 1875; Anodon and Dreissena are abundant in the neighbourhood of Oxford; Arca, Pectunculus, Spondylus, Solen, Mactra, and other genera were obtained by me through the good offices of the staff of Dr. Dohrn's zoological station at Naples, when I visited that establishment in the winter of 1875—76. My observations and notes have continually been controlled by Mr. Lankester, a few of the drawings in the plates were made by him, and the nomenclature, wherever it is new, is suggested by him.

Since the introduction into comparative anatomy of the searching methods of histological inquiry, there has been but one memoir published devoted to the consideration of the Lamellibranch's gill, viz., that of Dr. Carl Posner, which appeared in the 'Archiv fur Mikr. Anat.,' vol. xi, p. 517 (towards the end of the year 1875). My observations were commenced independently of that writer's results, and have led me to conclusions at variance with his on many points, as will appear in the sequel. Posner has given histological details with regard to the gill of Anodon only, and has confined his statements relative to the other Lamellibranchs to a series of highly instructive and, in the main, accurate diagrams of the types Mytilus, Ostræa, Pinna, Venus, Pholas, Scrobicularia, Mya, Solen, and Pecten.

The present communication will deal with the structure of the gill in the genera Arca, Mytilus, Dreissena, and Anodon. In a subsequent memoir it is my intention to deal with other types.

Without going into a full history of our knowledge of the structure of the gill-plates of Lamellibranchia, it is yet desirable to cite some of the writers whom we have to thank for the knowledge at present embodied in text-books of comparative anatomy. Cuvier and the zoologists of his genera-

tion regarded the Lamellibranch gills as a pair of vascular plates, placed on either side of the foot, and capable in some, if not all genera, of being broken up into a series of delicate adherent filaments; further anatomical investigation of them was not attempted. It was not until the year 1854 that Dr. Thomas Williams,[1] of Swansea, published his elaborate paper on the respiratory organs of Invertebrata, in which, with the same fatality which attended his work on another subject—namely, on the "segmental organ," the name which he gave to the structure still recognised by that designation—we find the greatest inaccuracy and fantasy inextricably interwoven with sound observation and far-reaching induction. Williams recognised the filamentar character of the Lamellibranch gill, but it was the eminent French zoologist Henri de Lacaze Duthiers who first showed the mode of development of this organ, and assigned to its parts a nomenclature which still holds its value, in his account of the development of the edible mussel published in 1856.[2]

In the same year the structure of the gill of Anodon (previously treated of by Rengarten) was investigated by Langer,[3] who made use of injections, and came to the conclusion—an erroneous one—that the large vessels present in the particular modification of gill presented by this genus were connected by a complete system of branchial capillaries.

No contribution to our knowledge of the structure of the Lamellibranch gill appeared for nearly twenty years. Whilst the work of Lacaze Duthiers and of Langer were confined to two isolated and very distinct types, that of Williams, in which a true comparative method extending to several genera was adopted, failed to command any confidence. There seemed, therefore, to be an exceedingly promising field of inquiry open to any one who, making use of modern methods of microscopical work, should examine the gills of a series of Lamellibranch genera with the object of determining the general plan of their structure and the particular modifications thereof, exhibited in particular cases.

When I had already applied myself to this investigation, the excellent memoir of Dr. Carl Posner made its appearance. Posner has the merit of having first clearly demonstrated by means of transverse sections that Langer was misled in the conclusion he formed from the evidence of injection; viz., that there is a capillary system in the Lamellibranch gill. Posner shows—what, indeed, had been

[1] 'Annals and Magaz. Nat. History,' 1854, vol. xiv.
[2] 'Annales des Sciences Naturelles Zoologie,' ser. iv, tome v, 1856, p. 1.
[3] 'Denkschr. d. Wiener Akad.,' Cl. viii to xii, 1856.

suspected, though never demonstrated (as he very justly points out in citing Gegenbaur's 'Grundzuge d. vergl. Anatomie,' 2nd edit., pp. 540 and 552)—that the tissue which forms the substance of the Anodon's gill is similar to the form of connective tissue which occurs abundantly in other parts of the Mollusca, and in so many Invertebrates, as well as in the Vertebrate embryo, and which the Germans know as Gallertgewebe (in England mucous tissue). It may well be termed, as Prof. Ray Lankester has suggested to me, "primitive mesoblastic tissue;" or, more conveniently in this case, on account of its relations to the vascular system,[1] "lacunar tissue." The characters of this tissue are discussed at length by Posner, who very properly directs the attention of the partisans of the various sides of the "Bindegewebefrage" to this elementary tissue. He might with equal propriety have directed their attention to the "primitive mesoblastic tissue" of a host of other Invertebrata, notably of the larger Vermes. Kollman[2] has also quite recently given a lengthy paper to this tissue in the Mollusca from the purely histological point of view—one which I shall not attempt to occupy.

The care which Posner has given to the histology of the "Najadenkieme" exclusively, and the use of osmic acid—which has, according to my experience, no advantage in this case over dilute chromic acid, and is not so efficient for many purposes as absolute alcohol simply, have not furnished him with true results as to the structure of the epithelium. On the other hand, he has been thus led to adopt the view from which I most emphatically dissent, that the respiratory organ of the Unionidæ is the prototype from which other varieties of Lamellibranch gill are to be derived. He, in fact, considers the Lamellibranch gills essentially as two

[1] "A true blood-system or blood-lymph-system is only possible where a mesoblast is developed, that is, in the Tripoblastica. In all Tripoblastica it is represented by lacunæ or channels, or by mere wide-setting of the cellular elements of the mesoblast, between and around which the movement of a fluid, so-called lymph, is possible." Primitive cell layers of the embryo, 'Annals and Mag.,' May, 1873, p. 332. The name 'lacunar tissue' is suggested by M. Milne-Edwards' 'système de simples lacunes qui fait les fonctions du reseau formé par les capillaires chez les animaux superieurs.' The nature of these lacunæ and the relationship of their tissue to the walls of the blood-vessels appears to have been fully divined by M. Milne-Edwards in 1844.

[2] 'Archiv für Mikrosk. Anat.,' part 3, vol. xiii, 1876. The reader is referred to this paper for a full discussion of the nature and relationships of the lacunar tissue. Kollman agrees with Posner in regarding it as a permanent form of the embryonic connective tissue of Vertebrates. Flemming (Habilitationschrift, Rostock, 1871) appears to have seen only that form of the tissue in which the cell-body is swollen and the lacunæ very narrow.

pairs of *membranous plates* placed on a pair on either side the foot. The filamentary structure of the gill is, according to him, secondary and due to a breaking-up of the gill-plate. In support of this view he appeals to an observation of Stepanoff's,[1] to the effect that in Cyclas two pairs of small membranous ridges precede the proper gill-filaments. Stepanoff's observation seems to me to warrant no such interpretation.

The chief conclusion to which my observations have tended is the exact reverse of this, and is to the effect that the gill-plates of the Unionidæ are a highly modified form derived from a simpler condition, in which the gills consist *not* of plates but of a series of juxtaposed independent *filaments*, such as we see in a less modified state in Arca and Mytilus. It has already been pointed out by Mr. Lankester[2] that these gill-filaments of the Lamellibranchia are the exact homologues of the tentacular filaments of the Polyzoa, and of the filaments on the spiral lophophor of the Brachiopods. To establish the possibility of the development of the more complicated forms of the Lamellibranch gill from such a series of simple free filaments will be to confirm Mr. Lankester's view as to the relationship of the ciliated filaments in the three classes, Polyzoa, Brachiopoda, and Lamellibranchia; the first two of which are better called Tentaculibranchia and Spirobranchia (Haeckel) respectively. This will be the main object of the present paper.

Outline of the Essential Constitution of the Lamellibranch Gill, and the Processes by which it becomes Modified.

The Lamellibranch gill which most nearly retains the primitive filamentary form is that of Arca; the gill of Mytilus is in a condition very nearly as archaic.

The constitution of the gill of Mytilus was first made clear by the excellent observations of M. de Lacaze Duthers, whose nomenclature will serve as the basis of that adopted in the present paper.

The gill of Mytilus, like that of all other Lamellibranchs, consists of two pairs of *gill-plates* placed on each side of the body, and separated by the foot, from the base of which on the right and left side, along a line[3] stretching from the mouth towards the anus, each pair of gill-plates arises. The

[1] Stepanoff, 'Archiv für Naturgesch.,' 1864.

[2] 'Quarterly Journal of Microsc. Science,' vol. xii, 1873. "Remarks on Rhabdopleura."

[3] This line, on account of its relationship to the lophophore of Polyzoa and Brachiopoda, Mr. Lankester proposes to call the "lophophoral line" or "lophophoral ridge."

outer plate on either side is known as the *right* or *left outer gill-plate*. The inner plate is similarly known as the *right* or *left inner gill-plate*. Each plate consists of a double row of exceedingly delicate *gill-filaments*, placed side by side and absolutely parallel to one another. If we examine one gill-plate closely by separating the parallel filaments, we find that the double row is not formed by two sets of filaments attached along the lophophoral line; but that for each gill-plate there arises from the lophophoral line but a single row of parallel gill-filaments, each one of which (the ant-umbonal surface of the Lamellibranch being its *ventral* surface), after descending in a ventral direction, suddenly bends upon itself at an acute angle, and passes upwards again, forming the second row of filaments which constitutes the plate. M. de Lacaze Duthiers has observed that this is the actual mode of growth of the gill-filaments in *Mytilus*. Each *gill-plate* thus consists of a single row of filaments bent on itself, so as to form two rows of filaments or *lamellæ*, with a space between them. One lamella is formed by the *descending* portions of the filaments, the other by the *ascending* portions. The ascending portions of the filaments are not attached to the lophophoral line, nor (in Mytilus) to the mantle. The ascending portion of each filament terminates in a hook-shaped process, which is closely adherent to the similar hook-shaped process of the two adjacent filaments, and probably in vascular continuity with them. Thus the *ascending* lamella or portion of the filaments is free in the region of the base or lophophoral line; the *descending* lamella or portion of the filaments, on the other hand, is here at its fixed point of origin. The outer gill-plate of each side of the animal has the free or ascending lamella placed outermost, or nearer the mantle; the inner gill-plate of each side of the animal has the free or ascending lamella placed innermost, or nearer the foot. Thus two complete filaments, one of each of the two gill-plates of one side of the body (say the left) seen in position as exposed by a cut dividing the mussel vertically into an anterior and posterior moiety, have the appearance of the letter W. The broad upper part of the letter is the base of the two gill-plates; the two angles on which the letter stands are respectively the apex of the inner (medial) and outer (lateral) gill-plates. The central angle at the base of the letter is the point of junction for each gill-plate with the lophophoral ridge. From this descends on the left-hand side the filament of the *inner lamella* of the *outer gill-plate*; it bends on itself, forming the *apex* or *angle* of that gill-plate, and ascends as the filament of the *outer lamella* of the *outer gill-plate*; it

then terminates as a free hook-like process facing the mantle (see Plate IV, fig. 10). Similarly, from the W on the right-hand side (supposing always that the letter represents the section of the two gill-plates of the left side of the animal) there descends from the central angle or point of lophophoral attachment the filament of the *outer lamella* of the *inner gill-plate;* bends on itself, forming the angle or apex of the inner gill-plate, and ascends as the filament of the *inner lamella* of the *inner gill-plate,* to terminate freely in a hook-like process facing the foot. Between each lamella of each gill-plate—that is to say, between the descending and ascending portion of each filament or limb of the W—is a space, the *interlamellar space.*

The W-like pairs of filaments succeed one another in a closely set series as we pass in the antero-posterior direction along the lophophoral line. Each w-like pair of filaments is separated from its successor by a narrow space or interval called the *interfilamentar space.*

Each filament in Mytilus is a hollow tube precisely similar (excepting for its reflection on itself) to the filaments on the lophophor of a Polyzoon (Tentaculibranch) or to those on the so-called arms of a Terebratula (Spirobranch). Each filament is clothed externally with a ciliated epithelium and has its inner wall strengthened by a chitin-like deposit. The cavity of the filament is, as in Tentaculibranchs and Spirobranchs, continuous at its point of origin in the lophophoral ridge with the body-cavity, cœlom or blood-lymph space, a special tract or "blood-vessel" being differentiated in connection with the lophophoral ridge. The tissue which forms the internal walls of the filaments is mesoblastic tissue of the primitive kind common in Mollusca and Vermes.

The course of the blood in the gill-filaments of Mytilus is not easy to determine. A great deal too much stress appears to have been laid on this question in connection with the gill of Anodon and other Lamellibranchs. It appears to be quite certain that the *main function* of these organs[1] is *not* respiratory but accessory to alimentation. We are likely enough to go astray if we seek for an elaborate afferent and efferent system of branchial vessels in an organ which chiefly serves the purpose of producing currents of water and in animals where the tissue oxidation is exceedingly sluggish, and the blood-lymph plasma of so lowly organised a character as to be freely discharged without injury to its owner, or diluted with large quantities of introduced water without affecting its physiological activity.

[1] See Alder and Hancock, 'Annals and Mag. Nat. Hist.,' 1856.

In Mytilus the movement of the blood, such as it is, probably proceeds from the lophophoral attachment down each filament, up its ascending branch, and so into a transverse canal,[1] which unites all the free hook-like terminations of the gill-plate; the transverse or interfilamentary canal opening at the anterior end of the series of gill-filaments into the base of the foot for the inner of the mantle, for the outer gill-plate near the mouth. On the other hand it is possible that in Mytilus and Arca there is no constant movement of the blood in the filaments in any one direction. It should be possible to ascertain this in young transparent specimens of Arca, where, according to the observations of Mr. Lankester, the blood-corpuscles are of about the same size as those of the common Frog of the same shape, and like them, *coloured red* by Hæmoglobin.

So far the structure of the Lamellibranch gill as exemplified by Mytilus differs little from that of the series of gill-filaments of the other two classes of Mollusca Acephala the Tentaculibranchia and Spirobranchia.

We now have to point to a structure which occurs in the case of Mytilus, Arca, and its allies, which effects a connection between the adjacent gill-filaments. These are small circular prominences on the sides of the gill-filaments carrying elongated cilia (see Pl. IV, figs. 4, 6, 7), *which interlock with those of the neighbouring filament*, and thus form *interfilamentar junctions*, or *ciliated junctions* as I shall call them. These were described by Lacaze Duthiers in the young Mytilus, and by Williams, but they have never been well figured nor has their altogether exceptional character attracted the attention which it deserves. The use of cilia in the manner thus indicated is entirely without a parallel in the animal kingdom. The knobs of interlocking cilia are disposed on the series of gill-filaments along more or less parallel transverse (antero-posterior) lines. They are the first indications which we have of that matting and fusing together of the constituent filaments of the Lamellibranch gill by transverse growths, whereby its plate-like character becomes ultimately developed to its full extent.

Intimately connected with the adhesion of adjacent gill-filaments by the interlocking of cilia is the further highly characteristic process by means of which in the Lamellibranchia as in other Molluscan classes, adjacent structures

[1] I have not been able to inquire into the existence of this transverse canal by means of injections. Its existence appears probable from the adhesion of adjacent hook-like terminations of the filaments of the free lamellæ, and from the structure of those terminal processes.

originally separate become fused into one continuous piece. This process M. de Lacaze Duthiers has spoken of as "la soudure;" I shall call it "concrescence," the name used by Haeckel for the similar phenomenon which occurs in the Calcispongiæ.

Posner and those who would advocate the membranous plate as the prototype of the Lamellibranch gill must entirely ignore the remarkable and exceptional process of "concrescence" of which we have excellent examples in the Lamellibranchia in other structures than the gills. It is a matter of observation that the free edges of the mantle unite in the siphonate Lamellibranchs by *concrescence* to form the siphons and the closed mantle sac. The siphon of the Dibranchiate Cephalopods is formed in the same way from the middle lobes of the foot.

An instance of abnormal concrescence in the gills of Anodon was brought under my notice by Mr. Lankester. In this case a torn portion of the inner gill-plate of the left side beyond the posterior edge of the root of the foot had become intimately adherent by concrescence to the inner surface of the inner gill-plate of the right side of the animal.

There can be no doubt after a survey of the facts, that concrescence plays a most important part—in fact, the essential part in the modification of the primitive gill-filaments of the Lamellibranchia.

As fully pointed out by M. de Lacaze Duthiers, the free outer lamella of the outer gill-plate and the free inner lamella of the inner gill-plate become *not merely adherent to* but vascularly continuous with neighbouring structures by "concrescence" or as one might term it "self-grafting."

In the genera Ostrea, Anodon, Pholas, Lutraria, as determined by M. de Lacaze Duthiers ('Annales des Sci. Nat. Ser.,' iv, vol. ii, p. 155), the external lamellæ of the external gill-plates are not free as in Mytilus, but are fused to the adjacent surface of the mantle by concrescence. Similarly the inner lamella of the inner gill-plate instead of remaining free as in Mytilus becomes in Anodon and other genera fused for a short space to the foot and where the foot ceases to divide the inner lamellæ of the inner gill-plates of each side from one another, their typically-free edges unite by concrescence, producing the partition between the cloacal and branchial chambers of the mantle.

Concrescence is not, however, confined in its operations to the production of adhesions of the gill-filaments to mantle and foot. By its operation the interlamellar space—the space between the descending and the ascending portions of the

filaments—becomes bridged over, and *interlamellar junctions* of various kinds effected. In Mytilus these consist of a few outgrowths from the internal or sub-lamellar surfaces of the filaments which are confined to a few spots, (see Plate IV, figs. 8, 9, 10), and form as M. de Lacaze Duthiers terms them, "véritables baguettes transversales assez longues." In other genera the *ciliary junctions* of Mytilus and Arca are replaced by fibrous and vascular interfilamentar concrescences, which have the form of transverse horizontal bands running antero-posteriorly at right angles to the filaments (see Plates V and VI).

When concrescence thus replaces the simple ciliary interfilamentar junctions of the more archaic type, the few tubular sub-filamentar outgrowths which by concrescence produce interlamellar junction in Mytilus are replaced by an exuberant sub-filamentar outgrowth, as in Dreissena and Anodon. This important and abundant outgrowth from the back of the filaments has an almost unlimited capacity for concrescence. It gives rise to long vertical interlamellar junctions (parallel to the filaments) disposed at regular intervals, and it obliterates that part of the inter-filamentar spaces left free by the narrow horizontal bands which join filament to filament, leaving only a series of irregular passages opening on the supra-lamellar and sub-lamellar surfaces by small inter-filamentar stomata. The loose, highly plastic tissue which thus grows out from the back of the filaments consists of lacunar tissue (*vide ante*, p. 45) covered by an epithelium. Channels and even definite vessels become excavated in it and the *primitive blood-carrying function of the hollow gill-filaments is superseded by the circulation which arises in the connected mass of sub-filamentar tissue.* With this loss of function the filaments loose more and more their primitive tubular character and become merely a supporting skeleton for the exuberant sub-filamentar outgrowth. In Anodon, where this condition is reached, the primitive gill-filaments no longer serve even as accessory blood-vessels. This assertion is contrary to the statements of Posner as to structure and the views of Langer, but it will be justified in treating more minutely of the Anodon-gill.

Another class of modifications to which the Lamellibranch gill-plate is subject consists in the destruction of the perfect parallelism of its two lamellæ and in the substitution of an undulating or fluted surface, so that the two lamellæ meet along one vertical line, then diverge and then again meet—the whole interlamellar space of the gill-plate being thus thrown into a series of sub-cylindrical cavities, each cavity

comprising in its wall a definite number of filaments. A series of diagrams illustrating the general arrangement of the filaments in these cases of which there are many varieties (*e.g.*, Ostrea, Cardium, Venus, Solen, Pinna) has been given by Posner. I shall defer any further consideration of these modifications of the Lamellibranch gill until I have completed my examination of those forms at my disposal, merely pointing out now that the inner gill-plates of Anodon present a distinct tendency towards the fluted type or "compound type" of gill as it has been called, which the outer gill-plates do not. This interesting fact has escaped Posner.

Details of the Structure of the Gill-plates in special Genera with reference to the Figures in Plates IV, V, VI.

Arca.—The gill-plates in Arca exhibit more clearly the primitive freedom of the typical two rows of reflected filaments than do those of any other genus, the examination of which has been recorded. There is but small manifestation here of the phenomenon of "concrescence." The inner reflected filaments are free from adhesion to the foot, the outer are free from adhesion to the mantle. Not only this but there is no concrescence of the two inner reflected lamellæ or rows of filaments behind the foot. The longitudinal lophophoral ridges on either side the foot from which the descending limbs of the filaments spring *are continued beyond the foot* as a pair of short spurs with a slight curvature, and are directly comparable to the lateral "arms" of the Brachiopod's or the Hippocrepian lophosphore. The only concrescence which I have detected in an examination of specimens from the Mediterranean, preserved in strong spirit, is at the apex or angle of the lamellæ where the reflected portion is united for a short distance by concrescence to the descending portion of each filament.

The filaments in large specimens of Arca (one and a half inches long) where longest measure as much as three quarters of an inch from base to apex; towards the anterior termination of the series they gradually become very short as well as at the free posterior projection of the lophophore. Each filament is rather band-like than cylindrical, the broad surfaces of the bands being anterior and posterior, whilst the narrow edges are lateral and medial or external and internal. On the broad surfaces of the filaments are placed at regular intervals the "ciliated inter-filamentar junctions" so as to form slightly undulating oblique transverse rows when the lamella is viewed as a whole. The ciliated junctions consist of large

epithelial cells, forming what may be called epithelial prominences (Plate IV, fig. 1). These cells carry long cilia which interlock, as might the hairs of two brushes, with the cilia of an epithelial prominence on the neighbouring filament. The band-like character of the filament and the circular outline of the epithelial prominence of a ciliated junction is well seen in fig. 3. It is not unusual for a filament to twist and turn over in this way when separated by teazing from the support of neighbouring filaments to which it is held by the interlocked cilia. The series of band-like filaments when viewed from the surface of the lamella may be compared to the vertically placed planks which form the sub-structure of a flooring. In fig. 1 the small portion of three filaments which is drawn is represented as seen in somewhat deep focus—deep enough, in fact, to give an optical section in the plane of the ciliated junctions. A superficial focus of the narrow surface of the filament would resemble that of Mytilus drawn in fig. 5 (left-hand one of the three filaments). The broad diameter of the gill-filaments in Arca, that is, the breadth of the surface on which are the ciliary junctions measured from the lateral (outer) to the medial (inner) border, averages $\frac{1}{110}$th of an inch. The narrow diameter measured at the surface of the lamella is the $\frac{1}{650}$th of an inch.

To ascertain the true structure of the gill-filament in Arca, as in all cases, it is necessary to cut a transverse section of it. Such sections may be obtained by embedding gill-lamellæ hardened in absolute alcohol, in paraffin. The sections may be advantageously examined in glycerine without the use of staining fluids, or the lamella may have been stained in picrocarmine before embedding, and mounted after cutting in balsam. On the whole I find that glycerine gives a better definition of cilia and fibrous structures in the various Lamellibranch gills than does balsam.

In fig. 2 a transverse section of a gill-filament of Arca is represented. It is seen to possess a single layer of epithelial cells, all of which are ciliated; those on the outer or lateral border (upper of the figure) being larger and columnar in form, and carrying longer cilia than those on the inner or median and anterior and posterior borders. A group of cilia of great length is placed on each side of the anterior border of the filament; the cilia may be called the latero-frontal cilia (Pl. IV, *lfc*, fig. 2), and the single row of epithelial cells which bear them are the cells of the latero-frontal epithelium. The histological details of this epithelium I have worked out more fully in the case of Anodon and Dreissena.

The section given in fig. 2 does not pass through a ciliated

junction, otherwise we should find appearances similar to those given in the upper part of fig. 6 (Mytilus).

Beneath the epithelium is a thin layer of chitinous substance coloured yellow in the figures. This is formed by the modification of the connective tissue (lacunar tissue). In the case of Arca and of Mytilus I have not ascertained the presence of protoplasmic corpuscles, or nuclei embedded in this thin chitinous layer, but on its inner surface which bounds the cavity of the filament, there are such corpuscles which give rise to septal filaments (*sep.*) limited in Arca to one series. These traverse the cavity of the filament and divide it into two chambers, a lateral and a medial. Possibly the two juxtaposed canals thus formed may have a functional importance.

MYTILUS.—The general form and arrangement of the gill-filaments constituting the gill-plates in the common edible mussel are familiar to most zoologists, and are well figured in the last edition of Cuvier's 'Regne Animal.' Like Arca, Mytilus has the ends of the reflected portions of its gill-filaments free. Like those of Arca, the adjacent filaments are held together by ciliated junctions. But there is a remarkable exhibition of concrescence in Mytilus which I have not met with in Arca, consisting of the sub-filamentar outgrowths which I call "interlamellar junctions." In Pl. IV, fig. 10, is represented diagrammatically (the drawing being shortened in proportion to breadth) a single filament of the outer gill-plate of the left side. The filament of the inner lamella (*fil.*) is seen descending from the base to the apex or angle of the gill-plate and returning on itself as the filament of the outer lamella, or reflected filament where it ends in a hook. The interlamellar junctions are represented as they occurred in a particular specimen. They are not *uniformly* in the position given in the figure, nor grouped precisely in the way there indicated throughout the series, but they run in irregular transverse rows along the series of filaments. Some of these interlamellar junctions are very long, and appear to have a great extensibility. When not extended they have the appearance of a bellows being deeply folded in their walls. This folding admits of their extension to a relatively enormous length. In fig. 9 one of these bellows-like processes is drawn in a state of semi-extension. Beneath its epithelium longitudinal fibres either elastic or muscular, I am unable to decide which, are seen. In fig. 8 parts of the descending and ascending limb of a gill-filament are seen. Each carries three epithelial prominences, *ep.* (ciliated junctions), and between them two interlamellar junctions (*ilj.*) pass in a

closely contracted condition. The power of contraction and expansion which obviously resides to a large degree in these interfilamentar junctions suggest the possibility of their contracting rhythmically; on the other hand, it is exceedingly likely that they are simply reservoirs capable of turgescence under certain physiological conditions.

Fig. 7 is drawn from a transverse section passing through the descending and ascending limbs of two filaments. The section coincides with the position of the interfilamentar (ciliated) and interlamellar junctions. The structure of the section of an individual filament is seen from this figure and from fig. 6 to be similar to that of Arca, the main difference being that the long cilia of the latero-frontal epithelium are carried on two rows of cells (*lfe′*, *lfe″*, in figs. 6 and 7), and further the lacunar tissue forming trabeculæ within the cavity of the filament is not limited to a single septum, but consists of *numerous* irregular bands. Professor Kollmann has quite recently ('Archiv für Mikrosk. Anat.,' 1876) shown that by means of the usual "silver process" a pattern of cell-outlines similar to those of the vertebrate lymphatics may be brought into view on the limiting surface of the filamentar cavity.

The form of the epithelial prominences (*ep.*) carrying the cilia of the ciliated junctions is shown in figs. 6 and 7.

The cessation of the chitinous deposit in that part of the filaments which grows out to form the interlamellar junctions is demonstrated by fig. 7, as is also the continuity of the cavity of the filaments of each lamella with the cavity of the interlamellar junctions. A blood-corpuscle (marked *bc.*) is seen in fig. 7, lying in the cavity of the interlamellar junction.

The filaments, as seen from the surface of the gill-lamella in specimens stained and clarified with Canada balsam, may be focussed at various depths, so as to give a series of longitudinal optical sections. In fig. 4 four filaments are represented so focussed as to show two rows of ciliated junctions (*cj.*). In fig. 5 three views are given of a portion of a filament taken at a part between two ciliated junctions, and focussed at three different depths. That to the left is the most superficial, giving the surface of the outer or lateral border of the filament, that is to say, the surface which forms part of the general outer surface of the lamella. In the centre are seen the nuclei of the "frontal epithelial cells" (*fe.*, and in figs. 6 and 7); on each side of these is a row of latero-frontal epithelial cells (*lfe.*) with long cilia, the bundles of cilia appearing each like a single and coarse cilium; seen

beneath these cilia is the blurred image of the lateral epithelium (*le.*).

The reader is referred to the figures and the appended explanation of the plate for further detail.

The narrow transverse diameter of the Mytilus gill-filament is $\frac{1}{440}$th inch, the broad diameter (that from its outer to its inner border) is $\frac{1}{130}$th inch. The interval between neighbouring filaments varies according to pressure, but averages $\frac{1}{1300}$th inch. The large latero-frontal epithelial cells which carry the long cilia are $\frac{1}{1500}$th inch in breadth at the surface of origin of the cilia.

ANODON.—Though Dreissena, on account of its position in the same family with Mytilus, would naturally next claim our attention, it will be best to take Anodon before passing to Dreissena, since Anodon and Unio have been studied by Dr. Posner, and give us a standard of gill-structure to which, when referred, Dreissena is found to approach in important respects, though retaining some features of the simpler Mytilus-gill.

In Plates V and VI a series of sections in different directions across the gill-plates of Anodon, and various enlarged drawings of parts of the gill-plate, are reproduced. The explanation which accompanies those plates will be found with them to supply nearly all the information which I have to give on the subject.

In Anodon the sub-filamentar outgrowths are large and abundant, so as completely to mask the primary tubular character of the gill-filaments. In figs. 1, 2, 3, 4, diagrammatic views are given of transverse sections cutting the gill-plate at right angles to the long axis of the filaments. The sub-filamentar excrescences are seen to form a layer of "lacunar" tissue, freely open to blood-turgescence and provided with large vascular trunks[1] (true vessels with definitely limited walls) which run parallel with the filaments, though few and far between, as compared with these latter, which I hold to be the primary vascular tubes of the Lamellibranch's gill. The large vessels occur at intervals of seven filaments in the outer gill-plate, at intervals of twenty or more in the inner gill-plate. They give rise to branches running at right angles to them, forming part of the sub-filamentar layer of each lamella. The branches are disposed at definite intervals, so as to form with the filaments a regular rectangular basket-work. The vertical element of the basket-work furnished by the filaments is perfectly regular and

[1] According to Kollman the silver treatment brings into view here also cell outlines as in the vessels of Vertebrata.

straight from base to apex; the transverse element furnished by the sub-filamentar vessels is of an undulating character, though in its main direction truly at right angles to the filaments.

Langer first showed by injection the presence of the large vertical vascular trunks and their horizontal branches. He was erroneously led to believe that the horizontal branches lead into a closed capillary system. As a matter of fact they do not, but open by a loosening or incoherence of their walls into the general space (continuous with the body cavity), which is the characteristic feature of the lacunar tissue, which forms the substance of the sub-filamentar outgrowths.

The horizontal vessels are often very ill-defined and of short extent, but here and there can be demonstrated in connection with the large vertical trunks (Pl. V, fig. 11 *v'*). When ill-defined they can yet be identified as more or less sharply-marked pathways or clear spaces in the lacunar tissue. Dr. Posner was the first to show by microscopic sections the continuity of Langer's vertical vessels with the surrounding lacunar tissue and the absence of a capillary system with definite walls. But he seems to have gone too far in identifying Langer's vertical and horizontal trunks *entirely* with the lacunar tissue, the spaces and trabeculæ of which he figures and describes. It appears from my sections (as well as from Kollmann's recent observations) that there are very definite walls, formed, one may say, by a *condensation* of the lacunar tissue, to the large vertical trunks of Langer, and there are even definite walls to the origins of the horizontal blood-pathways (see Plate V, fig. 11).

The layer of sub-filamentar tissue which occurs below each lamella of each gill-plate is formed by the concrescence (inter-filamentar) of the excrescences or bulgings-out of the deep[1] border of each gill-filament. The inter-filamentar concrescence of these outgrowths is very complete, and such as to leave only a series of undulating rows of small cylindrical passages opening by stomata or windows on the outer and on the inner surface of the lamella (Plate V, figs. 5 and 8). These narrow passages, which are the only parts of the interfilamentar spaces not obliterated by the concrescence of the sub-filamentar outgrowths, have a cylindrical shape, and run somewhat obliquely and irregularly. The horizontal elements of Langer's vascular system correspond with, and are excavated in, the continuous tracts of lacunar tissue which

[1] Deep in the sense of remote from the free outer surface of the gill-lamella.

separate these cylindrical passages. The stomata, by which the passages, "water-passages" as they may well be termed, open to the water outside the gill-plate at the one end, and to the water in the inter-lamellar space on the other, are seen in Plate V, figs. 14, 17. They are not set in strictly horizontal rows, but vary in position above and below a mean horizontal line. *The diameter of the stomata* on the deep surface of each lamella is considerably *smaller* than that of the *respective water-passages* into which they lead, whilst the passages do not contract, but become a little elongated at their termination between the filaments on the free surface of the lamella, forming thus a series of somewhat oval stomata at that end. The absolute size of the stomata, and of the lumen of the water-passages, as seen in section, varies considerably, the latter measurement giving $\frac{1}{1000}$th to $\frac{1}{250}$th of an inch.

The result of the narrowing (often abrupt) of the water-passages at the interlamellar surface is that in a transverse section, such as figs. 1, 2, 3, Plate V, a water-passage may be seen between nearly every adjacent pair of filaments; many of which—sometimes all—appear closed at the deep or interlamellar surface of the section by a continuous tract of lacunar tissue. The real state of the case is shown in the drawing of a solid block of gill-lamella, given in Plate V, fig. 8.

Interlamellar junctions.—At definite intervals the two lamellæ which form the gill-plate of Anodon are joined by outgrowths, constituting interlamellar junctions. These differ from the tubular bellows-like interlamellar junctions of Mytilus, in that they are not scattered cylindroidal outgrowths of the deep margin of individual filaments, but are long ridges running vertically, parallel with the filaments; they are rather additional outgrowths of the sub-filamentar mass of tissue beneath each lamella than outgrowths from individual filaments. They are coincident in position with the large vertical blood-vessels, and differ as do the latter in the inner and the outer gill-plates.

In the case of the inner gill-plate the large vertical vessels are disposed at intervals of about twenty filaments. Each vessel is found to lie alternately (not without exception) in the inner and the outer lamella, forming a large vertical ridge on the internal surface of the lamella (Plate V, fig. 3). These ridges, alternately belonging to one or other of the two lamellæ, unite very intimately by concrescence with the lamella to which they do not originally belong. Sometimes the union is more, sometimes less complete. The result is that the

interlamellar junctions in the inner gill-plate *contain* the large vertical vessels. In the outer gill-plate this is not the case.

The interlamellar junctions in the outer gill-plate are, like the vertical vessels, more numerous than those of the inner plate, occurring at intervals of seven filaments. They are long ridges of dense lacunar tissue, running vertically from base to apex of the gill-plate, and have a much greater size, measuring more from one lamella to the other than those of the inner gill-plate. In fact, they are capable of very great extension, which takes place when the outer gill-plate has its interlamellar space occupied by the Glochidian young of the Anodon (Plate V, fig. 4). This great depth of the interlamellar junctions of the outer gill-plate is their most remarkable feature, as compared with those of the inner plate. It is accompanied by a different disposition of the vertical vascular trunks; for, whilst these in the inner gill-plate lie *in* the interlamellar junctions, in the outer gill-plate they lie in the sub-filamentar mass of concreted tissue at the line of origin of the great ridges which act as interlamellar junctions. In consequence of this arrangement there are *two* vertical vessels in the outer gill-plate to each interlamellar junction; whereas there is only one to each junction in the inner plate. The arrangement of these parts in the outer gill-plate is no doubt correlated with its function as a brood-pouch. Histological changes go on in these parts of the outer gill-plate throughout the year, varying according to the presence, absence, or size of the Glochidia or ova. I have not yet followed out these changes in detail, and must point out that there is a certain amount of irregularity as to the development of the vertical vessels, especially as to the definiteness of their walls; so that in some parts and at some seasons they have well and sharply defined walls, whilst at other seasons and in other parts of the same outer gill-plate they appear rather as Posner holds them to be generally, namely, mere vertically-running lacunæ, or excavations of the lacunar tissue, which *may* in some cases have very little definition. This part of the subject I consider to require further investigation. It appears possible that the great vertical vessels of Langer may develope and be obliterated from season to season in the rapidly changing lacunar tissue of the sub-filamentar outgrowths.

Differences between the inner and outer gill-plates.—The difference just noted between the outer and inner gill-plates, due to the frequency of interlamellar junctions and their

relation to the vertical vessels, is accompanied by a further difference of form, which is obvious when the sections given in Plate V, figs. 2 and 3, are compared.

In the outer gill-plate the two lamellæ are parallel to one another and of equal thickness. In the inner gill-plate the outer lamella is thicker than the inner, and its surface is thrown into a series of curves. It bulges out considerably between each fixed line of interlamellar junction, so that we have a slight indication here of that plication of the gill-lamella which becomes so marked and important a feature of the architecture of the gill-plates in the so-called compound gills of Ostrea, Cardium, &c.

Structure of the Filaments.—The figures of transverse sections and surface views of the filaments given in the plates and the accompanying explanation will serve better than a long description, to place the results of my observations before the reader. In the main, they agree with Posner's, but I differ from him as to the epithelium, and also as to the cavity which represents the original vascular channel of the primitive gill-filament, as we see it in Arca and Mytilus.

The filaments have a uniform structure throughout the gill-plates of Anodon. They have lost their simple tubular character by (*a*) the resolution and outgrowth of their deep or sub-lamellar walls whereby the mass of sub-filamentar tissue is formed and (*b*) by the excessive thickening of the chitinous deposit, which whilst vastly increased on three sides of the original cavity of the filament, is altogether absent on the deep sides where the filament breaks out into a loose sub-filamentar growth of lacunar tissue (Plate V, fig. 12). In fact, from being hollow, tubes kept open by a firm deposit of chitinous matter the filaments have become comparatively solid rods with a median fissure corresponding with the primitive cavity, and as rods they merely support the loose lacunar (therefore blood-permeated) tissue which grows out beneath them.

There are no ciliated interfilamentar junctions in Anodon. In place of these we have very solid fibrous concrescences or junctions. The fibrous interfilamentar junctions of the Anodon's gill form regular transverse bands continuous horizontally across the series of filaments, and thus divide the long though narrow interfilamentar spaces into a series of rectangular spaces, about three times as long in vertical as in transverse measurement (Pl. VI, fig. 14). The surface epithelium of the gill-filaments is, of course, continued on to the fibrous interfilamentar junctions where it is continued inwards to clothe the water-passages and interlamellar surface. Each of the oblong rectangular spaces enclosed by the filaments and

transverse fibrous junctions coincides with the external opening or stoma of one water-passage (Pl. VI, fig. 14 *w*).

Thus it becomes probable that in the process of the evolution of the Anodon's gill from such a simpler form as that of Mytilus, the gill-filaments themselves first of all developed the horizontal transverse attachments which now present themselves as complete fibrous continuations of the connective substance of the gill-filament's wall. Then the deep or internal face (that forming the interlamellar surface) of the gill-filaments ceased to develope chitin and produced loose bulging growths of lacunar tissue, which extended *not only* along the vertical line of the filament, but across the transverse junctions, uniting to neighbouring outgrowths by concrescence. The concrescence has, however, always failed to block up a portion of the interfilamentar water-way, namely, a cylindrical passage running more or less obliquely upwards and backwards from each rectangular division of the inter-filamental space.

Thus the undulating horizontal arrangement of the internal stomata of the water-passages is explained.

It should be especially pointed out that sometimes, as an exception here and there, we find that concrescence has actually overstepped the limits thus laid down, and the water-passage corresponding to a rectangular interfilamentar area has disappeared, having been obliterated by the growing-together of its own walls.

The fibrous interfilamentar junctions consist of horizontal and obliquely crossed fibres (Pl. VI, fig. 14, *trf* and *b*), which I cannot agree with Posner in considering to be muscular. The relation of these fibres to the substance of the gill-filaments will be best understood by reference to a series of transverse sections of the filaments.

In Plate V, fig. 12, a transverse section of a filament is represented taken at a part where the sub-filamentar outgrowth or bulging of the deep surface is as small as can be found.

Beneath the epithelium to the front part are seen two semilunar masses (*ch.*): these are the greatly thickend chitinous walls of the filaments, but only correspond to one half of that wall as developed in Arca or Mytilus. Small nuclei (protoplasmic residue) are seen in the chitinous substance.

Passing to the lower part of the section we find there is no further chitinous deposit, but a loose trabecular tissue (*lac.*) amongt the mesh-work of which float blood-corpuscles (*bc.*). The semilunar chitinous masses show in the section each a smaller more highly-refracting and yellow-coloured body, which we find on comparison with the longitudinal section

(Pl. VI, fig. 14) to be the transverse sections of rod-like bodies. These rod-like bodies—the well-known "Stäbchen" of German writers—appear to be simply condensed or firmer portions of the larger mass of chitinous substance. It is interesting to compare these sections with those of Dreissena (Pl. VII, figs. 25, 26) in which the rods are absent.

Looking now at the longitudinal section (Plate VI, fig. 14), we see that where the transverse fibrous junctions are developed, the rods bend a little outwards and become very thin and small so as *almost* to cease. They do not, however, quite disappear at the level of the transverse junctions, but are continuous from end to end of each filament, merely becoming small at every transverse interval. At the base of the gill—the line of origin—the rods of neighbouring filaments join, forming an arch, the anterior of one filament joining the posterior of the next in order, as we pass forward from anus to mouth. I have not figured this arrangement which is drawn by Posner, who calls attention to the similar arrangement in the chitinous rods of the gill bars of Amphioxus.[1]

Now, if we take a section across the filaments at the level of the transverse junctions we shall find the relationship of the fibrous transverse bands to the chitinous half-wall of the filament. Such a section is exhibited in Pl. V, fig. 13. The chitinous rods are seen reduced to a minimum size, the semilunar masses of paler chitinous substance are broader and larger than in the other section and break up deeply into fibrous substance, the fibres being attached to a central row of corpuscles.

There is no question whatever that *here* at least there is complete obliteration of the primitive cavity of the gill-filament. Even though we may admit that the space between the semilunar masses in fig. 12 represents the primitive cavity, it cannot be regarded as Posner regards it, namely, as a distinct canal. It is widely open to the general cavity of the lacunar tissue and at every transverse junction is entirely obliterated. Compare with this the condition of Dreissena (Plate VII), which also furnishes interesting evidence for the relationship of the chitinous deposit to the cell-elements of the lacunar tissue. The chitinous deposit is merely to be regarded as a peculiar and largely developed intercellular product.

The Epithelium of the Gill-filaments—I have devoted special care to this part of the subject, since my results differ from

[1] The similarity between the structure of the pharynx of Amphioxus and the Lamellibranch gill is an instructive example of what Mr. Lankester has called homoplasy as opposed to homogeny ('Annals and Mag. Nat. Hist.,' 1870).

those of Posner on this head. Figs. 20, 21, 22, 23, in Plate VI, give my results most accurately, and where the other figures of Anodon (in Plate V) differ from these, such differences are to be regarded as inaccuracies or diagrammatic licences. We can distinguish on the gill-filament a frontal epithelium (*f.e.*), latero-frontal (*l.f.e″.*) and lateral epithelium (*le, le′*), the last-named continuing into the water-passages and clothing the interlamellar surfaces. All the cells of the epithelium are ciliated, those of the latero-frontal rows (a single row on each side the frontal epithelium) have the longest cilia, far out reaching those of the other cells; the frontal epithelium and the more forward cells of the lateral epithelium come next with finer and much shorter cilia; and lastly, the in-lying lateral epithelium has but very short cilia.

The cells of the line of latero-frontal epithelium deserve especial notice. Posner speaks of them as "einfach durchborten," but entirely omits to notice the fact that they are very much larger than the neighbouring cells, as shown in fig. 23. When seen from the surface of the lamella each latero-frontal cell appears like a goblet-cell with a single coarse flagellum issuing from it in place of a mucous product (see fig. 21). When turned over or seen in the transverse section of the filament the cell is seen to be broad and a little flattened, the single flagellum proves to be an adhering group of long cilia, which apparently issue from the mouth of the goblet-like cell by a series of pore canals, that is to say, there *is* a cork or 'Propf' to the cell as to intestinal epithelium, but it is traversed by these cilia. The nucleus is large and clear and deeply placed with but a small amount of stainable protoplasm around it. Staining with picrocarmine colours the nuclei of all the epithelial cells intensely and also a small amount of surrounding protoplasm, but the whole cell is not deeply coloured. Hence the appearance presented by the frontal epithelium in fig. 20, and in the similar view of Dreissena filaments in Plate VII.

The form and arrangement of the epithelial cells will be best understood by reference to Pl. VI and its explanation.

I have found absolute alcohol to the fresh Anodon, and mounting the sections in glycerine, to give better results as to the epithelium than does osmic acid.

Lacunar Tissue.—In Pl. VI, fig. 18, is given a view very highly magnified of what Mr. Lankester considers a typical piece of lacunar tissue. It is from a sub-filamentar outgrowth. The nuclei of the original cells are seen surrounded with a small quantity of granular protoplasm which gradually gives place to a slightly metamorphosed substance, forming

the trabeculæ, uniting one such cell-centre to another. In fact, we have a slightly modified series of branched corpuscles joined by their branches, the branches being band-like rather than filamentous. In the spaces between the trabeculæ floating blood-corpuscles are seen; a granular coagulum sometimes occupies these spaces. The fluid in the spaces is the blood-lymph. This kind of lacunar tissue occurs most abundantly as the representative of "mesoblast" in the Anodon's gill and other parts.

In fig. 30 a dense modification of the "mesoblastic" tissue is shown, which cannot be distinctly separated from lacunar tissue because it passes into it. The cells here are spindle-shaped and closely packed, but leave occasional narrow passages among them. You have only to separate them from one another and pull them out into connecting bands and processes, and you get ordinary lacunar tissue.

This dense lacunar tissue with fusiform cells occurs in the interlamellar junctions of both Anodon (Pl. V, fig. 9) and Dreissena (Pl. VII, fig. 25). It probably very readily passes into the wide-set variety with trabeculæ, and *vice versâ*. It occurs in many other parts of Lamellibranchs and other Molluscs, and has been wrongly looked upon as the chief or only kind of "connective tissue" in these animals.

The lacunar tissue of fig. 18 is the typical variety. It resembles the earliest formed mesoblast in embryonic Gasteropods and other animals, where, however, in parts it is contractile, a property of which we have no evidence in the gill.

In (fig. 19) a drawing is given to show how the lacunar tissue behaves itself in condensing to form a blood-vessel. The floor of the little horizontal vessel v' is formed by such fusiform cells as those seen in fig. 30; in both cases mere modifications of the trabecular cells.

Measurements of Anodon Gill-structure.—The breadth of the gill-filament in a well-grown Anodon taken from the outer edge of one row of latero-frontal cells to the outer edge of the opposite row is $\frac{1}{400}$th of an inch.

The length of the large cells of the latero-frontal epithelium is $\frac{1}{1130}$th of an inch, and the breadth $\frac{1}{3000}$th of an inch.

The lumen of the water-passages as seen in sections parallel with the surface of the lamella varies in diameter from the $\frac{1}{1000}$th to the $\frac{1}{250}$th of an inch.

Dreissena.—The structure of the gill in this genus presents highly interesting points for comparison with Mytilus (in which genus it was formerly placed), and with Anodon.

On the whole the gill-structure of Dreissena is decidedly nearer to that of Anodon than to that of Mytilus. So far as

I know, it has never yet been described. That Dreissena, being a *fresh-water* form, should agree in its gill-structure with Anodon, another *fresh-water* form, rather than with Mytilus, a far more closely related though *marine* form, is in itself a most noteworthy fact. A reference to Plate VII and its description will place the main facts before the reader. The specimens which I have studied were procured from the Oxfordshire Canal, where *D. polymorpha* is very abundant.

As in Anodon, we have in Dreissena gill-plates in which concrescence has fully asserted itself. There are no "ciliated junctions" but *fibrous* inter-filamentar junctions (fig. 28, page 9, Plate VII) as in Anodon, forming a rectangular basket-work with the filaments. Further, the sub-filamentar outgrowths form an extensive layer of tissue beneath the filaments proper, united into one continuous mass by concrescence, excepting for the "water-passages," which are arranged much as in Anodon. The descending and ascending lamellæ of each gill-plate are united by vertically continuous interlamellar junctions, which resemble those of the outer (brood-bearing) gill-plates of Anodon. There are large vertical vascular canals present in the sub-filamentar tissue, similar to those of Anodon. These are disposed similarly to the large vertical vessels in the *outer* gill-plate of Anodon, but with less regularity, sometimes occurring *between* the points of origin of inter-lamellar junctions instead of *at* those points. It is remarkable that this should be the structure of the Dreissena's gill-plate, since we do not know that it has a brood-bearing function as has the similarly constituted plate of Anodon. I could ascertain no difference of structure between the outer and the inner gill-plates of Dreissena.

The most remarkable differences between the gill-plates of Anodon and Dreissena are the smaller size of the filaments in Dreissena; the presence of two rows of long ciliated latero-frontal epithelium as in Mytilus, in place of one row as in Anodon; the larger relative size and smaller number of epithelium cells on the filaments of Dreissena; the smaller relative development of the sub-filamentar tissue; and the different structure of the chitinous deposit in the filaments. This chitinous deposit is a thick horse-shoe shaped mass in transverse section resembling that of Anodon, and totally different from the closed delicate ring of chitin which we find in a transverse section of the Arca or Mytilus filament. It is even more exuberant (see Plate VII, fig. 26) in development than the similar structure in Anodon, but presents no trace of the denser "rods" which are differentiated in the latter genus. A careful examination of the chitinous

deposit in the filament of Dreissena shows us the presence of rings of deposit or varying tension, which would no doubt make it an interesting object for the polariscope (see Plate VII, figs. 25, 26).

If the section be taken near the horizon of a transverse fibrous junction, we find (see upper part of fig. 25 and fig. 26) that the chitinous mass does not retain its open semi-canalicular character, but becomes a closed solid mass, with a central tract of corpuscular elements (*nch.*). Moreover, at its deeper end we find connections with the fibrous or trabecular elements of the lacunar tissue, and also curious lobe-like additions of chitinous matter added to the chief mass, and penetrated by obscure fibrous septa. This extension and thickening of the chitinous skeleton of the Dreissena gill-filament only takes place at the horizons of interfilamentar transverse fibrous junctions. Between these horizons the chitinous axis of the filament is a half-canal, and in section of a horse-shoe shape, or rather like a letter U with its sides thickened internally. The lacunar tissue of Dreissena exhibits fewer *band-like* trabeculæ than does that of Anodon; the processes of its cells being rather more fibrous and filamentar in character. The interlamellar junctions are of the condensed variety of lacunar tissue, with fusiform cells (fig. 30, Plate VI), but in parts exhibit a looser structure (compare the two in fig. 25, Plate VII). Pigmented cells with dark brown granules, besides blood-corpuscles, are found floating in the blood-lymph, or attached to the processes of the lacunar tissue.

Measurements.—The filaments of Dreissena have a short diameter of only $\frac{1}{1000}$th of an inch as compared with $\frac{1}{400}$th inch in Anodon. The epithelial cells are of about the same size in the two genera; the larger latero-frontal cells of Dreissena being somewhat shorter relatively to breadth as compared with Anodon.

The object of the present paper has been to explain the structures illustrated in the accompanying plates, on the hypothesis that the Lamellibranch gill is not primitively a membranous plate, but a series of independent filaments. This hypothesis, availing itself of the principle of *concrescence*—of the existence of which we have independent proof—*does* satisfactorily explain all the details of structure which I have submitted to the reader's notice. If I shall have proved that—at any rate so far as the four genera, Arca, Mytilus, Anodon, and Dreissena are concerned—the filamentar hypothesis is the correct one, I shall feel satisfied. I reserve the discussion of other types for a future occasion.

Résumé *of* Recent Contributions *to our* Knowledge *of* "Freshwater Rhizopoda." Part III. Heliozoa (*Desmothoraca*) and Monothalamia (*Monostomata*). Compiled by W. Archer, F.R.S.

Desmothoraca, Hertwig and Lesser.

In this group the skeleton is formed of one single solid piece enclosing an inner cavity and with peripheral openings; at the same time it is distinguished from the single-chambered test of the Monothalmia by its homaxial fundamental form.

There is not any ground to regard the Desmothoracous skeleton to be, as it were, composed of individual pieces once isolated and then fused into one hollow-globular entirety, but rather it must have been so *ab initio*, and in it the irregularly arranged apertures must have been preformed. Both the known forms (one of which is now for the first time described by Hertwig and Lesser) appertaining here possess a more or less elongate and slender *stipes*, on the upper end of which is borne the hollow perforate skeleton containing the living body-mass, and the lower end of which is attached to some external support.

Hedriocystis pellucida, Hertwig and Lesser (this Journal, vol. xvi (1876), Pl. XXII, figs. 21 and 22),

is characterised by the possession of a stipitate, single-cavitied skeleton. The stipes (0·05—0·075 mm. long) (fig. 21, *s*) is attached by its dilated base to algal filaments and such like foreign bodies, whilst the upper end passes without any sharp limitation into the contour of the skeleton (fig. 21, *t*). The latter is ovate-elongate and in the direction of the stipes, like it delicate and pellucid, and so constituted that its wall, at all the places through which the pseudopodia pass, projects as so many pointed prominences, the whole lending to it the aspect of a knobbed club with stellate projections. Except at the apices of these projections, which are perforate and destined to allow the passage of the pseudopodia, the wall is otherwise closed.

The formation of the skeleton begins with the production of the stipes (fig. 22, *s*), thereupon succeeded by the deposition of the skeleton, and both by the agency of the protoplasm. When fully formed the round body-mass is freely poised within the cavity of the skeleton, as if suspended by the pseudopodia. It consists of a finely granular protoplasm, and contains an oval nucleus (with nucleolus) (figs. 21 and

22, *n*), whose length approaches one third to one fourth the diameter of the body; towards the margin of the latter occur one or several vigorously pulsating contractile vacuoles (figs. 21 and 22, *c c*). The pseudopodia do not subdivide; they show a distinct granular current; sometimes even minute vacuoles could be seen passing up and down them.

As regards reproduction, the authors record simple fission as readily to be observed. They frequently saw two bodies of about equal size within one and the same shell, each provided with its nucleus, and possessing its contractile vacuoles. Once they saw a small individual, which, no doubt, proceeded from self-division, furnished with a minute stipes, but still without a shell (fig. 22). The plane of division stood vertical to the direction of the stipes. Besides subdivision, encysting occurs, but the authors were unable to follow out any further development.

Clathrulina elegans, Cienk.[1] (vol. xvi (1876), Pl. XXII, figs. 23—25).

Cienkowski was disposed to regard the perforate hollow-globular skeleton of this now pretty-well known form as composed of numerous polygonal plates. This view Hertwig and Lesser seem rightly to contradict; it certainly seems to be but a single connected structure throughout; the openings are roundish-polygonal, and their margins surrounded by a more or less elevated rim, which in fully-grown examples can be seen at the equatorial periphery of the sphere standing off like papillæ or very short blunt spines. The stipes is regarded by Hertwig and Lesser as tubular; so it certainly appears to be, its base can be often seen to terminate in a number of rootlike processes by which it retains a hold on foreign supports, or indeed often on the shells of other individuals of its own species. As to the sarcode body as is known, it is comparable to Actinophrys, but as the original discoverer, Cienkowski (I believe I myself found it, however, considerably prior to him, and showed it at a meeting of the Dublin Microscopical Club and this considerably in advance of the date of my own paper, preceded by Cienkowski's only by a very short interval) observes, unlike that of that form, that here the peripheral contour passes into a number of short lobelike projections terminating in the pseudopodia.

Hertwig and Lesser distinguish between two kinds of vacuoles—one enclosing food-particles, the other simple fluid-cavities; the latter mostly projecting at the periphery in a somewhat hemispherical manner and are partly contractile.

[1] Cienkowski: 'Archiv. f. Mikrosk. Anat.' Bd. III, p. 311, t. xviii.

The rounded nucleus (with nucleolus) is very difficult of detection, but it exists (figs. 21 and 22, *n*).

As to Greeff's view of a homologue to the central capsule whence radiate axial threads of pseudopodia, Hertwig and Lesser are unable to concur in it. The pseudopodia are very fine, granular and readily anastomose, which circumstance Hertwig and Lesser seem very justly to suppose is against the existence of such threads; apart from the difficulty of detecting an inner thread within structures themselves, appearing under even very high amplifications as themselves but mere threads.

The assimilation of the incepted food particles takes place within the vacuoles before alluded to, but a body too large to pass inwards through the apertures of the shell may be surrounded by the protoplasmic substance of the combined pseudopodia, and so digestion be carried on in a vacuole thus appearing as it were *impromptu*.

Hertwig and Lesser have followed out the modes of reproduction described by Cienkowski:—After complete self-division of the body-mass the two portions pass out through an aperture of the shell, and at once establish themselves, first, producing a stipes, followed by the appearance of a shell. A further mode is by encysting, the body-mass first breaking up into a number of individual portions, each by and by surrounded by an externally spinulose membrane; after a pause the cysts develope pyriform, nucleated, seemingly biflagellate, zoospores, followed out by Cienkowski to the formation of young Clathrulinæ. A third process was observed by Hertwig and Lesser, characterised by a repeated subdivision, and, in the formation of zoospores, it possesses a connection on the one hand, with the reproduction by encysting, and on the other, in the want of a membrane to the segmented portions, it is comparable to simple division. In all cases the authors found the body-mass within the shell broken up into three portions, each of which appeared to give off pseudopodia. Of these fission-products, two were mutually alike in size and smaller than the third, which latter contained approximately about an equal quantity of protoplasm to that of the other two taken together. The first two left the shell simultaneously, or at least one but a very short time subsequent to the other. As already described by Cienkowski, during this process the organisms project an amœboid process through one of the foramina of the fenestrate skeleton, causing a figure-of-8- shaped constriction of the body during exit; this accomplished, the now free body forms an elongate ovoid zoospore, with a homogenous anterior,

and a granular posterior end (Pl. XXII, fig. 23). In the former could be seen the nucleus with its nucleolus, almost completely filling it, and in the latter two or three contractile vacuoles; at the anterior apex appear two flagella as long as the body, by means of which the organism advances with a slow and uniform rotating movement. After about half an hour or more it settles down vertically on some object, where to develope its stipes, and whilst assuming a globular figure, continues, without advancing, to rotate on its longitudinal axis. As soon as this has ceased the pseudopodia become quickly developed on all sides, and the body passes into the form of a naked Clathrulina. About this time the stipes becomes apparent as a clearly-shining, sharply-contoured circle on the surface of the body (Pl. XXII, fig. 24, *s*). If the organism be brought into a profile view, it is seen that the stipes which becomes firmly attached to the substratum, soon growing to a considerable size, takes its origin in an umbilicus-like depression of the body and forms a direct process of the body-mass (Fig. 25). It thus originates as a protoplasmic structure and only subsequently becomes developed around it the tubular skeleton-portion of the permanent stipes. In the progress of growth the protoplasmic prolongation filling the tube must become retracted, for in the fully-formed Clathrulina the soft body-mass stands no where in connection with the stipes.

The authors were not able to follow out the development of the fenestrate skeleton, but doubtless it is preformed by protoplasm, they at least found that some young individuals still naked, but with stipes, showed the pseudopodia mutually united by transverse connections; these forming, at a little distance from the body-surface, beautiful arcades, most probably the bases for the development of the future fenestrate skeleton.

Reverting to the larger subdivided portion of the original body-mass left behind within the shell, and which at first maintains its place therein, still displaying its numerous pseudopodia as if it were making an endeavour to make good the loss in body-substance which it had suffered, the authors arrived at no definite results. In one case of which they had under observation, the object died from want of accession of a fresh supply of water, after they had had it for a whole day long under observation, without any perceptible alteration. On another occasion they found the shell empty, on renewing their observations on the following day, but as they saw two zoospores hovering near they supposed that the body left behind (as described) had once more subdivided, and

that the products of such fission had passed into the state of zoospores. Should this procedure (i.e., the exit of all products of subdivision) be the general one, the mode of reproduction here described might be simply referred back to that mode by fission described by Cienkowski—the only difference being that each product of division again repeatedly subdivides into two, and produces a zoospore. As regards both modes, analogies are offered by Microgromia.

That examples of this species are sometimes found seated on preceding individuals, in which fact Greeff thought to see an "inclination to the formation of Colonies," Hertwig and Lesser regard as purely accidental; and in this they coincide in my own previously expressed opinion—such examples are seated on those preceding them in the order of time, simply because the latter afforded the nearest fulcrum for the young individuals resulting from simple subdivision without passing into the zoospore-state, and hence capable of but a comparatively very restricted locomotive power.

Having thus given a *résumé* of the foregoing beautiful observations of these authors on Clathrulina, one is tempted however, to urge that there hardly seems a necessity to place *Hedriocystis pellucida*, Hertwig and Lesser, in a separate genus—that the two organisms are indeed specifically most distinct, cannot for one moment be questioned. I almost think this will be readily evident on looking at the authors' own diagnostic characters.

Hertwig and Lesser, in concluding their long and most important work, regard it as proven that a separation of our Heliozoa from the Radioloria is justifiable (and I must now, as before mentioned, give my own adhesion to the view), but they point out several of the lacunæ in our knowledge requisite to be filled up, and certain vexed points to be settled by repeated and extended researches, ere we have a complete and true conception of the whole of the conditions of organisation of the Heliozoa. Thus it would be desirable to know, How far a differentiation of the body-mass into endo- and ectosarc prevails in the group—Whether a differentiation of the pseudopodia into a granuliferous investing stratum around a homogeneous axis is a more widely spread character than would as yet appear—What the mode of ending of the axis and its histological significance, and last (not least)—What the bearing and details of the various reproductive processes? The classification (propounded by them) of the group can hence be regarded as but provisional, the more so as the relatively small number of genera and species does not yet render it

practicable to do for the Heliozoa what Häckel has done for the Radiolaria and Carpenter for the Foraminifera.

Previous to entering upon the recently described accessions to the Monothalamatons Sarcodina, appertaining to the fresh water, two very distinct forms found in sea-water, having Actinophryan resemblances, to say the least, claim a brief notice.

Actinolophus pedunculatus,

Eilh. Schulze[1] (Plate XXII, figs. 26, 27, Vol. XVI, 1876).

Though marine in habitat the form named above seems to claim a notice in the present résumé. Seated on various hydroid Polypes, and even on sea-weeds, the author found at various times of the year, but mostly in summer, this remarkable stipitate animal form, in outer habit resembling a Podophrya occurring in its company, but in no way belonging to the Acinetæ, but truly appertaining to the Rhizopoda.

The stipes is cylindrical (length, 0·06 c. 0·1 mm., breadth, 0·003 — 0·004 mm., figs. 26, 27); without any basal plate or expansion of any kind; its lower end stands directly upon the substratum, whilst at the upper end it bears the body. It is perfectly colourless and hyaline. The author concludes from the outer layer appearing doubly contoured that it consists of a delicate tubular sheath of chitinous nature, enclosing slight refractive contents. In the interior a few, usually three, mutually equidistant parallel fine lines can be seen mostly running longitudinally through its whole length; but in some cases confined to the upper portion of the stipes only (figs. 26, 27).

The body borne at the apex of the stipes is usually pyriform, its narrower end downwards (fig. 26), but the by no means inconsiderable contractility of its mass enables it to assume various figures, from ovate to globular. Apart from the pseudopodia it is always smooth and of a simple contour (length, 0·02—0·03 mm.; breadth, 0·015 mm.). The hyaline plastic ("zahflüssig") basic substance (as is usual in Sarcodina) shows numerous fine and coarse more or less refractive granules embedded therein. The author could not perceive any special membrane nor any ectosarc. In the interior occurs constantly a *nucleus*, which strikes the eye as much by its extremely large nucleolus as by its excentric position (fig. 26). The oval rarely globular, homogeneous, and rather strongly refractive smoothly-contoured nucleolus has a diameter of about 0·003—0·004 mm., and shows around

[1] Schulze, 'Schultze's Archiv,' Bd. X, p. 392, t. xxvii, ff. 1—9.

it a narrower clear granuleless envelope, whose outer contour (corresponding probably to a membrane) is only rendered distinct after application of acetic acid, then appearing doubly contoured—in living examples, however, always closely encompassed by the granules of the surrounding sarcode. The nucleus never occurs central or indeed even within the broader portion of the body, but constantly placed in the narrower basal part, and here not in the longitudinal axis, but laterally (fig. 26).

But in the centre of the anterior broader part of the body a structure is to be perceived, as to the nature of which the author has not been able to gain any certainty. It appears as a dark globular body of about 0·001 mm. in diameter, and mostly, as regards its position, corresponds to the common centre of the pseudopodia (fig. 26). Sometimes, indeed, the author thought he had perceived fine lines therefrom to the pseudopodia, but could not make himself certain of the existence of such; neither could he determine if the fine lines running longitudinally through the stipes were continued into the body.

Sometimes particles of an orange colour could be perceived in the body-substance; these were not like the rounded, smooth, often coloured, granules of many Heliozoa, but appeared as minute irregularly-shaped rough fragments of various sizes, and occurred not in the darker centre, but only in the outer granular region. They sometimes occur in great quantity, when they impart a brownish-red colour to the body; sometimes they are very wide apart, and again they are wholly absent.

Crude food was seen only seldom, then lying in the outer part amongst the colouring granules.

The author never saw any pulsating vacuoles.

The pseudopodia are numerous, but occur only at the outer and upper part of the body, never close to the stipes. They are very fine, long, and pointed. On a thin axile part there hung granules and clusters of finely granular substance. Whether there be really a more solid axile thread present, the author could not decide, though of that impression. A fusion of pseudopodia he had seen in only a few cases; and that only due, as it would seem, to some mechanical shock or during the capture of some foreign body as food. The author was struck by the fact that they never seemed to become wholly retracted into the body-mass; no doubt a considerable amount of contraction under certain circumstances took place, always stopping at a certain point, or nearly equidistant from the body, so that they would

form a kind of crown around it, each apex showing an agglomeration of contracted granular sarcode, lending a considerable amount of resemblance to certain Podophryans. The author, to account for this phenomenon, was disposed to assume the presence of an extremely hyaline, though imperceptible, gelatinous envelope surrounding the apparently naked body, preventing the abrupt retraction of the whole of the pseudopodia and causing the agglomeration of the granular substance at its periphery.

But, as well as the examples as above described, others occurred with a *distinct outer covering*, and at the same time other alterations were perceptible, possibly indicating a resting condition preceding a subdivision. A perfectly pellucid gelatinous envelope directly and everywhere surrounds the body, permeated by fine dark parallel lines proceeding from the stipes and becoming lost in the body-sarcode. A more advanced stage could be seen in other cases in which a layer of delicate fine strongly refractive plates could be recognised on the surface of the gelatinous investment (fig. 27). By degrees these seem to become thicker; their contours, however, not yet marked out by the more evident, presently showing themselves as solid, tolerably regularly hexagonal plates. Taken altogether, they form an approximately globular, ovoid, or pyriform case, prolonged into a similar coating down the stipes. It is striking that these plates do not touch by their lateral margins, at least the author always saw clear intervening narrow zones, which could only be interpreted at intervals between isolated plates or as thinner parts of a continuous membranous coat. Owing to their withstanding concentrated sulphuric acids the author concludes they are siliceous. Whether when fully formed the old stratum of gelatinous substance still remains the author could not satisfy himself.

Further modifications consisted in the subdivision of the nucleus, regularly preceded by an elongation, an assumption of a biscuit-shaped figure and final breaking up into two portions, each surrounded by its own special hyaline envelope (fig. 27). The two newly-formed nuclei now recede from one another. At the same time the pseudopodia may remain quite unaltered and fully extended, even though the distinct rudiments of the plates were present (fig. 27). But with the further development of the plates the pseudopodia became wholly retracted, and at the same time the little dark globular central body disappears. From the latter circumstances the impediment to the nucleus attaining the

middle region of the body seem to be removed, for now the two nuclei can be met with at any part of the body.

The "encapsuled" examples mostly appeared to possess a shorter stipes than the naked, but the author did not feel certain whether there was any real contraction or that short-stalked forms were more prone to become encapsuled.

The connexion of the axial inner portion of the stipes with the body, by means of the longitudiually running parallel lines, is ever maintained; these could be followed sometimes, even up into the sarcode body-mass (fig. 27).

Any further data as to a subsequent subdivision or other mode of reproduction the author's opportunities did not afford him.

Whether this interesting form might possibly coincide with *Lecythia elegans* (Strethill Wright)[1] the author could not determine. There is a considerable resemblance in the stipes, and on the capitate figure of the pseudopodia on becoming retracted; but the figure of the body of that form drawn out at its outer extremity does not agree, nor does the statement that it is enclosed in "a closely-fitting envelope." More closely related possibly to *Zooteira religata* (Strethill Wright)[2] would appear the present form; that form, however, possesses a short mucous covering surround-the basis of the stipes into which the whole animal can be fully withdrawn, having a thick muscular band with lateral processes in the stipes; it possesses also a granular region, designated by Wright as *ectosarc*, surrounding the richly granular but non-nucleated body (endosarc), from which the pseudopodia are said to proceed.

Lithocolla globosa, Eilh. Schulze[3] (Pl. XXI, fig. 9, Vol. XVI, 1876).

Whether the form called *Lithocolla globosa* by Eilhard Schulze, and found by him in the washings of some sea-weeds and mussel-shells from the Baltic, really belongs to the Heliozoa or not, is, so far as the author's experience of it reaches, still undetermined. Were it so it would probably justify the formation of such group of which it would be typical, characterised by the heliozoan inclosing itself around by a more or less loosely apposed stratum of foreign arenaceous and other foreign particles, comparable in a measure to that of Difflugiæ, but not coherent into a "test."

[1] S. Wright, 'Ann. Nat. Hist.,' vol. viii, p. 123 (1861).
[2] S. Wright, 'Quart. Journ. Micros. Sci.,' vol. ii, p. 217 (1862).
[3] Schultz's 'Archiv,' Bd. X, p. 389, t. xxvi, f. 8—10.

When the author's attention was first called to the Sarcodine in question, the object before him appeared hardly more than an accidental globular agglomeration of sand, nor, until this at first sight scarcely noteworthy little mass began to *move* spontaneously, did he perceive the fine linear pseudopodia projecting around from between the sand particles, and realise the fact that a living organism really lurked inside.

To judge from the figure and from the author's description of the mode of motion fixed on the pseudopodia, this form really appears to have the aspect of a heliozoan so encompassed by foreign arenaceous particles, but on pressure the author found that these did not form a connected test, but were only more or less loosely applied, whilst at same time the sarcode body then assumed the appearance of a discoid or elongate mass; continued pressure caused the whole to pass into a shapeless commingling of softish finely granular sarcode, with the sand-particles now embedded therein.

In the ordinary condition the pseudopodia are long (about double the body-diameter), extremely fine, linear, radially extended, rather rigid, and never inosculating; mostly the foreign particles lie closely applied to each other, allowing no very perceptible interspaces; but sometimes only a comparatively few are present (occasionally a few diatom frustules), leaving considerable vacant interspaces. The body-mass appears usually to have shown a reddish-colour when closely surrounded by foreign particles, but to have appeared colourless when these were few. But unfortunately the author was unable to gain any insight into the body-structure, not even to discover if it possesses a nucleus. Of course on the result of further investigation in this regard depends the reply to the query as to the proper location of this sarcodine.

MONOTHALAMIA.

Under the designation Monothalamia are comprehended a large group of Sarcodina, with such pervading community of structure that no difficulty can be felt in regarding them as forming a related group proceeding from common primordial forms. Hertwig and Lesser after giving at some length the views of the older authors, and a *résumé* of the gradual growth in our knowledge of their characteristics, and after descanting upon the clearly proven untenability of any real distinction between simple vacuoles and contractile vesicles, formerly regarded as of considerable importance, proceed to point out the great distinguishing feature, owing to which

their separation as an independent group becomes necessary, and that is the *monaxial* character of the body, enclosed in a single-chambered usually firm and unyielding test; at one or both ends of the test it possesses a definite and permanent opening for the emission of the pseudopodia. The axis leading therefrom to the opposite side the authors designate the principal or longitudinal axis, although it may in some forms be shorter than that transverse thereto. If the two axes are alike the test, viewed from either end of its "longitudinal" axis, will be circular, a *simple* monaxial fundamental form; if they are unlike the monaxial fundamental form becomes *bilaterally symmetrical*. In this monaxial fundamental form, then, of which the bilateral symmetry is but a secondary differentiation, consists the pervading distinction of the Monothalamia from the homaxial Heliozoa. The test is either a pure secretion product of the organism where it is either smooth or of variously ornamented peculiar structure, or it is built up or partly composed of foreign constituents such as arenaceous particles, diatomaceous frustules, &c., cemented together. The pseudopodia proceed outward from the animal within only through the one great frontal opening through which, of course, is carried inwards from without the food, or such an opening occurs (in a very few forms) at both ends (Amphistomata); if (as mostly) there be but one opening that extremity may be regarded as the frontal or "oral," the opposite closed end as the "aboral" (Diplopola, Häckel), whilst when there are two openings they appear to be equivalent and there is no evident differentiation of the poles (Haplopola, Häckel). Still so far as I can see the pseudopodia do appear to be usually given off, notably more copiously and to reach a greater length at one end than at the other.

The body-mass never advances beyond the dignity of a simple cell; in the Monostomata the posterior part is usually the more homogeneous and contains the *nucleus*; the anterior is the more granular, and usually presents some vacuoles, often contractile. In the Amphistomata the nucleus occupies the middle point between the two openings. In the multinucleated Arcellæ the nuclei lie towards the margin of the discoid body.

The pseudopodia are of multitudinous character in the different genera or species. They are cylindrical, blunt, unbranched, non-coalescing, granuleless, very slow in action, on the one hand, or delicate, linear, or inflammatory, pointed acutely, much ramified, constantly coalescing or highly granular and presenting an active "circulation" and vigorous

contractility on the other; between such most varied intermediate conditions occur, or these characteristics may be combined in the most manifold but seemingly ever characteristic, manner. Still they all readily enough fall under one or other of the two great categories designated as Rhizopodous and Lobose.

As to reproduction—simple division formation of zoospores, and encysting have been observed.

The unexpected and very interesting discovery of the Foraminifera being *nucleated* Sarcodina, made simultaneously by Professors E. Schulze and R. Hertwig—an abstract of whose recent papers is given in another part of the current number of this Journal (which see)—imparts a fresh interest to our freshwater Monothalamla, which are thus shown to have a direct relationship to the marine forms through Gromia, &c.; they are, in fact, Imperforate Thalamophora.

Monothalamia Monostomata.

In the discrimination of subgroups no characteristics are seemingly more important than those presented by the pseudopodia, but those possessed by the test as regards its structure and its figure are of considerable value, in some forms more so than in others—the structure being more of generic, the figure more of specific importance.

The test itself may be discoid, cylindrical, or flask-shaped, whilst the monaxial fundamental form may be further developed to a bilaterally symmetrical one, which modification may be brought about according toone or other of these modes:

(1) An axis vertically transverse to the "longitudinal" may surpass the rest in growth so that the test becomes broader in this direction, and hence laterally compressed (thus *Plagiophrys scutiformis*, Hertwig et Lesser, with its smooth test, or *Euglypha compressa*, Carter, with a test formed of superimposed imbricated plates).

(2) That portion of the test terminating in the "mouth" grows to one side, which thereby comes to lie more or less lateral. (Thus *Microgromia socialis* (Arch.), Hertwig, with a smooth test, or *Cyphoderia margaritacea*, Schlumb., with test similar to Euglypha).

(3) The principal axis of the test undergoes a curvature (thus the snail-shell-like test of *Difflugia spiralis*).

These specialities of outward configuration are valuable specific characters, if not available for the formation of genera or larger groups. The presence or absence of special structure in the test itself and the presence or absence of foreign

bodies in its constitution are seemingly of more importance in the formation of genera, whilst as regards larger groups the authors are driven back to the characteristics possessed by the pseudopodia as the most comprehensive and prominent, and at same time natural and constant, as already long ago laid down by Dujardin and Carpenter: these are the two groups known as Lobosa and Rhizopoda.

Monothalamia Lobosa.

The pseudopodia are either cylindrical or finger-like, or form broad plates or lamellæ, or they end in a conical manner. They are always blunt at the apex, never very long, rarely and but slightly branch, their protoplasm homogeneous, very rarely any granules passing into them and then only near the base.

The test is either a pure secretion-product or formed by the cementing together of foreign bodies.

Arcella vulgaris (Ehrenb.)

For the first time seemingly a correct description of the structure of the peculiar test of this somewhat variously shaped and otherwise pretty well known, and at least common, species is given by Hertwig and Lesser.[1] Two plates, an outer forming the superficies of the test, and an inner applied to the body of the *Arcella*, are united by a honeycomb-like structure, whose hexagonal cavities form prismatic spaces standing vertically to the surface. These spaces the authors took to be filled with fluid; in order, however, to test if real hollows or cavities the authors applied a solution of carbonate of soda, adding thereto acetic acid, subsequently washing out with water: the hexagonal spaces then for the most part became filled with air and therefore appeared with the black border indicative of that condition. They therefore conclude that the appearance of the marking on the Arcella test is not due to granulation as Dujardin supposed, nor to perforating canals as held by Ehrenberg, nor built up of individual plates as Claparède and Lachmann, as well as Carter, assumed. Wallich, indeed, spoke of a "symmetrical reticulation" and of "hexagonal interspaces;" still Hertwig and Lesser doubt if he altogether correctly appreciated the structure, as how otherwise could he come to the surprising conclusion that *Arcella vulgaris* could be but a subspecies or even species of Difflugia? A query which I may venture heartily to re-echo.

[1] Loc. cit., p. 93 et seq.

In the body-mass occur several nucleolated nuclei and contractile vacuoles. Encysting sometimes is met with, but no further development has been noticed. The so-called "conjugation" accompanied with a kind of rhythmical temporary interchange of the plasma is a common phenomenon, interpreted by Hertwig and Lesser as merely the expression of an act of division, inasmuch as so frequently one of the individuals is of the deep reddish-brown of the mature form, the other yellowish or colourless, the latter presumably the younger; the two individuals presently separating and each "going its way."

Since Hertwig and Lesser's work, however, Bütschli has published a memoir,[1] in which he seems to return to the view that the conjugation has, at least, sometimes, a greater significance than merely the expression of an act of division. He found (as sometimes happens) three all alike highly coloured individuals conjugated; afterwards, when separated, these showed a portion of the body-mass broken up into a number (as many as nine) of minute "Amœbæ," with nucleus and contractile vacuole. These made their way out from the parent-test, and Bütschli supposed them to be germs of young Arcellæ, but was not able to follow out their development any further. How such amœboid germs develope tests and become Arcellæ is uncertain, and, adds the author, "this would be of great interest, for I can hardly suppress the doubt that such forms as the *Pseudochlamys patella*, Clap. et Lachm., and the *Arcella patens* of the same observers, may not belong to the development-cycle of *Arcella vulgaris*." This latter view I venture to hold, with Hertwig, as altogether unfounded.

[1] O. Bütschli, "Zur Kenntniss der Fortpflanzung dei, *Arcella vulgaris*," in 'Schultze's Archiv,' Bd. xii, p. 459, t. xxv.

(*To be continued.*)

REVIEW.

Further Researches into the History of the Bacteria. Conducted by and under the direction of Professor COHN.[1]

THE rapid appearance of the first two parts of the second volume of these invaluable Beiträge, edited by Professor Cohn, so soon after the publication of the concluding part of the first volume, affords a curious illustration of the uncertainty which one is made to feel about the publication of German journals; however, we may congratulate ourselves on the fact that two fresh papers on the history of the Bacteria are to be found in the second part. The first is by Professor Cohn himself on the "Biology of Bacillus;" the second by Dr. Koch, on the "Ætiology of Splenic Fever." This latter has been referred to by Professor Tyndall, in his lecture on "Fermentation and its Bearings on Disease,"[2] which has, I suppose, been read by every one who takes an interest in the problems, which these lowly organisms offer for our consideration. In continuation of my account of the former researches,[3] I will now enter into the details of this fresh publication.

In preparing the former I found it would conduce to clearness if I followed Professor Cohn's method of numbered paragraphs. This method I will again adopt.

1. The first paragraph deals with the discussion as to spontaneous generation, and points out how the supporters of this doctrine had practically come to suppose, that substances which were submitted to the temperature of boiling water were unable to produce living matter.

2. But such a supposition has been shown to be incorrect, and Dr. Charlton Bastian has, in 'Nature' (Feb. 10th, 1876), brought a list of nineteen "important witnesses, among whom were physiologists of the first order," to show that "skilled observers" had already noticed the phenomenon; prominent among substances which so behave are peas; and Cohn relates how the manufacturers of pots of preserved vegetables at Lübeck have,

[1] 'Beiträge zur Biologie der Pflangen,' 2er Bd., 2es Heft, 1876.
[2] 'Fortnightly Review,' November, 1876.
[3] 'Quarterly Journal Microscopical Science,' July, 1876.

since 1858, been obliged to cook them in a solution of 28 per cent. of salt, at a temperature of 108°, to prevent the putrefaction of their contents, as in warm years nearly half of the pots prepared were in the habit of going bad. The salt solution has been found to fulfil, at the higher temperature, all that was demanded of it. In France a temperature of 117°, without salt, has been found satisfactory. After reference to the work of Professor Tyndall and others on this matter, Cohn goes on to show how he has, since 1872, been busied, either in his own person, or that of his pupils, with the study of this most interesting question; he has already proved that dense substances, such as peas or pulse, are bad conductors of heat, and that the temperature of the surrounding fluid is communicated to them only with difficulty, so that Bacteria hidden in clefts of their substance have been hardly submitted to the temperature, which the thermometer has marked. Dr. Horvath has dropped into Cohn's nutrient fluid one drop of Bacteria, and has found that under such conditions an exposure to a temperature of 60° to 62° C. for an hour has been sufficient to destroy the power of reproduction. And Dr. Schroeter, who also worked under Cohn's direction, found the maximum temperature at which activity of the Bacteria was perceptible to be 58°.[1] With this we should compare the majority of results, which show that 35° to 50° is the average of mortal temperature, ordinary protoplasm coagulating at 43°, and other protein compounds at 60° or even at 70° to 75° C.

But we must not forget the influence of the length of time during which the heat is applied, lower temperatures for longer periods being within, of course, certain limits as powerful as higher temperatures for shorter periods.

3. Now comes the question, Why these contradictory results? One answer, and the fairest yet offered, is that which Cohn himself has given, namely, that the spores which are embedded in firm substance, such as peas or cheese, are not acted on by the heat; and also that some forms of Bacteria, as Bacillus,[2] have "lasting spores," capable of resisting heat for a long time; and Dr. Roberts ('Phil. Tr.,' clxiv, ii, p. 474) has shown the extreme difficulty of "sterilising" certain infusions of hay; to these results, so scientifically conducted, Cohn has lately, with the assistance of Mr. Robert Hare, a Canadian, addressed himself. For the variations in the mode of experiment which experience suggested I must refer the reader to the original; suffice it to say that in unboiled infusions *Bacterium termo*, *Micrococcus*, *Mycothrix* (rosary chain), *Bacillus*, and *Leptothrix*, were largely found. Infusions that were boiled gave various results, accord-

[1] Cf. Bd. i, op. cit., Heft 2, p. 220, and Heft 3, p. 35.
[2] Cf. 'Quart. Journ. Micr. Sci.,' July, 1876, pp. 272, 273.

ing to the various conditions under which the experiments were performed, as the appended list will show at a glance. In *infusions boiled for less than fifteen minutes organisms were, without exception, developed.* The following gives the results of several hundred experiments, carried on at various times during a period of nine months.

In hay infusions there were developed—

		Organisms.	No Organisms.
		Duration of Heating at 100°.	
1875.			
28th Oct.—Acid	.	5 to 15 min.	
Neutral	.	5 to 15 ,,	. 30 min. and more.
7th Nov.—Acid	.	5 to 20 ,,	. 30 ,,
Neutral	.	5 to 15 ,,	. 20 ,,
18th Nov.—Acid	.	5 to 20 ,,	. 30 ,,
Neutral	.	5 to 15 ,,	. 30 ,,
24th Nov.—Acid	.	5 to 90 ,,	. 120 ,,
Neutral	.	5 to 120 ,,	
1st Dec.—Acid	.	30 to 60 ,,	. 90 to 180 min.
Neutral	.	30 ,,	. ,,
1876.			
5th March.—Acid	.	20 to 80 ,,	. 100 to 120 min.
Neutral	.	20 ,,	. 40 to ,,
5th July.—Acid	.	5 to 30 ,,	. 40 to ,,

4. Since it is clear that there must be some difference between the organisms which were able to survive so fiery an ordeal, and those which are killed by it, we must make use of the microscope, and our previous knowledge to settle the matter; examined thus, the survivors were all found to belong to the genus *Bacillus*, and none to *Bacterium*, and among *Bacilli* to the species *B. subtilis*. A figure of them is given in the plate attached to the paper, and a full discussion entered into, in this fourth paragraph of the original memoir; the only point to which I shall here refer is that Cohn noticed, for the first form, felted gelatinous coils and chains of Bacilli embedded in the "glia," in the specimens obtained in these experiments.

5. In the homogeneous interior of the *Bacillus* fibres there appeared highly refractive corpuscles, each of which consisted of a cylindrical doubly-contoured spore; always were these arranged in rows. To follow these out, glasses *à immersion* were required (as much, sometimes, as 1650 diameters); the *Bacillus* fibres are there seen not to be truly unjointed, but to consist of joints, each of which is about four times as long as it is broad; within each is a spore, which does not quite fill the space; their mode of development seems to be comparable to that of *Nostoc*, or *Cylindrospermum*. The chains of Bacilli separate into their constituent joints. When the spore leaves the mother-cell it

possesses a gelatinous envelope, which is not easily affected by water. But development goes no further in the same infusion; if some be, however, put with an infusion which has not passed

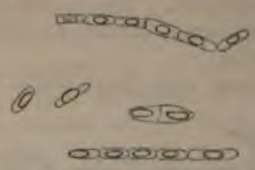


FIG. 1. Spore-formation in the *Bacillus* of the hay infusion. × 1650. Cohn's drawing.

through the bacillar fermentation, the spores will be seen to swell, and to push out at one end a tail, so that they become "köpfchenbacterien," like in appearance to the spermatozoa of vertebrates;[1] the highly refractive bodies disappear, the tail begins to move and to get itself jointed; soon—but care must be taken to keep out *Bacterium termo*—felted masses of bacillar fibres will be evident to the naked eye.

It will be interesting to follow Cohn into the note which he appends to this paragraph, for the purpose of drawing attention to the striking analogies between this bacillar fermentation of hay infusions and the course of many infectious diseases; incubation in the former lasts for twenty-four hours, during which time the affected fluid is apparently unchanged, although the most active increase in number of *Bacilli* is in progress; on the third day the paroxysm—represented by the troubled appearance of the fluid—is reached; the remission—represented by the clearing of the fluid—sets in on the fourth day, when spore formation commences. A few days later all is over; the ferment organisms have passed into the spore state; henceforward the fluid is safe from this form of fermentation, but may be highly infectious to others.

6. The conclusions to which Cohn is led are:

(1) In boiled fluids *B. termo* is not developed, nor is any other organism, as far as we yet know, save only Bacillus; and this is not because the fluids after boiling are incapable of supplying nutrition to these Bacteria, as the mere dropping of some *Schizophytæ* into a boiled infusion will show; but for the simple reason, that a temperature much higher than 50° causes their protoplasm to coagulate.

(2) *If Bacilli become developed in the boiled hay infusions, it is because their mode of development protects them from the influence of heat.* The spores, the history of which we have already

[1] Fig. 6, Pl. XX, 'Quart. Journ. Micr. Sci.,' July, 1876.

traced, are imbedded in the hay; if they are not exposed to the action of water too long (and they are wetted with great difficulty) they are able to withstand the action of heat at 100°. Compare with this Pasteur's experiments on the dry spores of Penicillium which were heated to 121° without losing their vitatality. Further than this, the oily nature of their interior, and the layer of air which separates it from the cell-wall, recall to us the conditions of Leidenfrost's experiments, and help us to understand the resistance with which these spores, when not swollen by water, are enabled to offer to heat of fifteen minutes' duration. The longer the boiling lasts the more uncertain the result, as more and more spores lose their capability for development.

(3) *In all cases where organisms have developed from organised matter, that has been boiled, spore-produced Bacilli (and nothing else) has been found.* Cohn has already shown that in Bastian's turnip and cheese infusions the insidious enemy that has been the origin of so much discussion has been the lasting spore of the *rennet-Bacillus,* which has basely lurked in the cheese.[1] So with peas and albumen;[2] and he very fairly concludes that the results of experiments with infusions of hay should not incline us to believe in the probability of spontaneous generation.

(4) Some experiments which Dr. Eidam has been making for Cohn lead to the following conclusions:

I. At a temperature of 47° to 50° the Bacilli increase actively, and go through their ordinary development; the other *Schizophytæ* which were in the infusion were killed at this temperature.

II. At a temperature between 50° and 55° all increase in number and development ceased; the swarming and growing fibres were killed, but the spores lived for at least seventeen hours.

III. Although, as a rule, exposure to a temperature of 60° for twenty-four hours was sufficient to make the infusion sterile, yet in a few cases some *Bacillus* spores survived 70° and 80°, even when they had been subjected to so high a temperature for four days.

(5) With regard to the existence of *Bacillus* in unboiled infusions, Cohn finds that its activity is suppressed by *Bacterium termo* in hay infusions and such like; Billroth has rendered the supposition that Bacilli are found in the serous fluids of the tissues of animals extremely reasonable; and here Cohn makes a statement which is in accordance with the views of Professor Ray Lankester, for he now thinks that the *Leptothrix* form,

[1] Cf. 'Quart. Journ. Micr. Sci.,' 1876, pp. 272-3, and Pl. XX, fig. 6.
[2] P. 277.

often found in diseased tissues, belongs to the genus *Bacillus*, "although their genetic connection is still unknown (dunkel)." Our author has himself pointed out the great probability of the normal existence of Bacillus-fibres in the stomach of cattle.

(6) Lamenting the slight knowledge which we have of the physiology of *Bacillus*, especially from the chemical point of view, Cohn comes to the conclusion that for their perfect development free exposure to the air is necessary, while their ferment activity goes on with great intensity in vacuo. But putrefaction proper is not produced by *Bacillus;* to effect it "the ferment of putrefaction," that is *Bacterium termo*, must be present, hence the generic difference of these forms is again indicated.[1]

(7) With the facts in his mind, of which an account has just been given, the delight of Cohn may be conceived, when he heard from Dr. Koch of his investigations into the ætiology of splenic fever, and on his seeing his experiments and his specimens; these were examples of the species called *Bacillus anthracis*, but the difference between them and the *Bacillus* of hay infusions—*B. subtilis*—are so slight that the same figures are used in explanation of both papers.

Cohn's last words are full of hope; although we know not yet if the Spirochete of marshy water and of recurrent fever, the Micrococci of foul springs or of decayed food, and of typhus or diphtheria, have severally any genetic connection; yet the great light that has of late, that is, since these subjects have been studied with any energy, been thrown on them, in so short time, bids us hope for more to come.

The title of Dr. Koch's paper is 'The Ætiology of Splenic Fever (Milzbrand-Krankheit), based on the History of Development of *Bacillus Anthracis*.'

1. The introduction relates how the writer was brought to the

[1] As in Cohn's last paper there is a great deal of species-making, with which compare Prof. Lankester's remarks on the subject ('Quart. Journ. Micr. Sci.,' July, 1876), it is right to note that he here says that he considers his genera *Micrococcus Bacterium*, *Bacillus*, *Vibrio*, *Spirillum*, and *Spirochæte* as natural, but his species as purely provisional; I fully expect that continuous observations would show that genetic relationships exist between some of these; and I would draw attention to the fact that in his last classification *Leptothrix* is a term of *generic* value. Prof. Lankester has called my attention to a paper by Dr. Warming, of Copenhagen, to whom Cohn was indebted for many of his new specimens, described in the previous essay; the Danish naturalist has been good enough to give at the conclusion of his paper a *résumé* in French; from it I will simply quote "Les bactéries sont douées en réalité *d'une plasticité illimiteé*, et je crois qu'il faudra renoncer au système de M. Cohn et de quelques autres savants, qui caractérisent les genres et les espèces d'apres leur forme." The extent of Dr. Warming's investigations entitles any opinion he may put forward to a most respectful hearing.—F. J. B.]

study of this question by the discussions which arose on the results obtained by Davaine.

2. The next section commences with the following statement: Bacilli increase with enormous rapidity in the blood, and in the fluids of the tissues of living animals, by increasing in length and dividing transversely. As a convenient animal for injection Koch uses mice, a small incision being made at the root of the tail, and as small a drop as possible of the fluid containing the Bacilli being injected into the system; to see whether these organisms did not after a time pass into another form, and that he might also be provided with fresh material, Cohn injected several mice—once as many as twenty—one after the other, each succeeding mouse from the one that had preceded it. The results were always the same; the spleen was enormously swollen, and filled with a large number of crystalline-looking rods of varying size, never exhibiting movement or spore formation; they increased in number solely by division.

The number of Bacilli found in the blood varies with the animal injected; in the guinea-pig it was enormous, sometimes even exceeding that of the blood-corpuscles; in the rabbit much smaller, so that sometimes several drops had to be examined before any were found; in the mouse often *nil*.

The next statement is: in the blood of dead animals, or in other suitable fluids, the Bacilli grow to very long, straight, leptothrix-like filaments (within certain limits of temperature and with the presence of air), while the formation of numerous spores goes on at the same time.

The truth of this statement can be tested very easily by dropping a minute portion of a spleen thus affected into some perfectly fresh serum, or *Humor aqueus* of a cow. The means which Koch employed for preventing evaporation will be found in his paper. After the specimen has been kept for fifteen or twenty hours at a temperature of 35° to 37° it may be examined; the centre will be found almost unchanged, of the appearance represented in the accompanying woodcut. As the centre is left, elongated and bent forms are met with, till, towards the edge of the glass cover, fibres are found more than a hundred times the length of the rods in the middle of the glass. Of these last many will be found to have lost their crystalline appearance and homogeneous structure, their contents being finely granulated, and small highly-refractive granules being set at regular distances from one another. Quite at the edge, the fibres contain perfectly formed spores of an oval shape and highly refractive, resembling a string of pearls.

After much exercise of patience and ingenuity the author was at last able to watch the steps of spore formation under the

microscope. The phenomena thus observed were similar to those

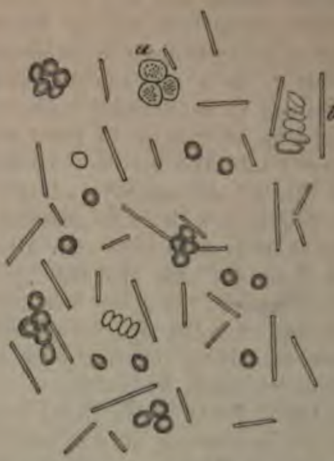


FIG. 2. *Bacilli anthracis* from the blood of a guinea-pig; crystalline rods, some beginning to divide transversely, or to get bent, with blood-corpuscles (*a*, white, *b* red). × 650. Koch's drawing.

indicated by the different stages of development which have been just detailed.

The spores of *Bacillus anthracis* under certain conditions of temperature, nutrition, and presence of air develope immediately to the *Bacilli*, which were seen in the blood.

The impression that this is really the state of things, and that the spores are not merely broken-down products of the bacillar fibres, is supported on *à priori* grounds by the natural history of Fungi and Algæ, and was confirmed by the injection of spores alone into the blood. Placed in a drop of aqueous humour each spore was seen to take an oval shape, and to become imbedded

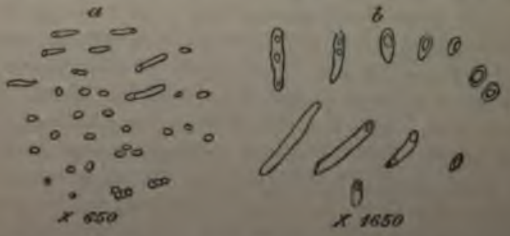


Fig. 3. Growth of the spores. The spore is elongating into a cylindrical corpuscle, the highly refractive mass remaining at one pole, gets smaller, breaks up, and finally disappears.

in a circular mass which surrounded it. This at first loses its circular form, and becomes elongated in the direction of the long axis of the spore, so as to become of an elongated ovoid form, the spore remaining at one pole. As the envelope increases in length the spore becomes paler and smaller, breaks up into several parts, and finally disappears altogether, as the accompanying woodcuts show (fig. *a* was drawn by Koch, *b* by Cohn). Koch has even been successful in getting a second generation of spore-forming fibres.

This section of the paper concludes with drawing attention to the fact that these observations have not been made once, but repeatedly, and that the author has had the benefit of Professor Cohn's examination of his specimens. The negative results to which C. O. Harz appears to have come ('Allgem. Med. Central-zeitung,' 1876, No. 33) have no value in the face of his, which are positive.

3. To know whether the presence of *Bacillus anthracis* fully explains the occurrence of splenic fever, it is necessary to have some further information about its life-history and the conditions under which it survives the sufferer, of whose death it has been the cause, in order to spread its disease still further.

To see how long they could survive the effects of drying, Koch tried the following experiments:—Blood or spleen from an infected animal was dried in a shady place, exposed to the air; with this a mouse was injected, and the results watched under the microscope. That which was dried in very thin layers lost its infective power after twelve to thirty hours, and, at the same time, its power of growing into elongated fibres, in the incubating apparatus. Thicker layers retained their powers for two or three weeks, and some, still thicker, for four or five. After a longer time they were never capable of producing the disease, and it may be said that such substances, thus dried, are never able to produce splenic fever, unless they are also able to produce spores from the fibres; and, inversely, as the conditions of successful cultivation, Koch found that 35° was the best for their development, the spores appearing after twenty hours; at 30° they took thirty hours; at 18° to 20° two and a half to three days; below 18° the appearance of spores was exceptional; and below 12° the growth of fibres was never observed. On the other hand, at 40° development of spores was rare, and appeared to cease at 45°.

As to the necessary conditions of air-supply, the following results were obtained:—*Bacilli* were rubbed up with the blood, aqueous or vitreous humour of an ox, and placed in a well-corked glass. Very rapidly did there appear a powerful smell of putrefaction; the *Bacilli* disappeared after twenty-four hours

without the fibres enlarging, and lost their infective powers. That this death was due to the absence of oxygen was shown by placing a drop of blood infected by the Bacilli under the microscope; examined by the microspectroscope, it gave the bands of oxyhæmoglobin; the fibres in this drop increased four or five times in length in three hours; but then the oxygen was clearly used up, as the presence of the absorption-band of reduced hæmoglobin showed. From this moment the growth of the basillar fibres ceased, although true putrefaction had not set in. One of the first signs of death is the opalescence of the fluid and the falling to pieces of the fibres, as is well illustrated in Bollinger's article in Ziemssen's 'Handbüch der Spec. Pathol. und Therap.,' p. 465. In connection with the discussion which is going on as to the "plasticity" of the Bacteria, I should add that Koch says that he has never observed any passing of the fibres into *micrococci*, or the like; but why they should do this when dying I can hardly see, and wonder that any one can expect it, especially as we know—thanks to Koch—the morphology of the alternation of generation in this species of the *Schizophytæ*; and, further, I imagine that no one who has any clear ideas as to what forms are would imagine that a species, a form, or what you please to call it, will or can, under our eyes, pass into a form of totally different physiological and, unfortunately, we must add, pathological, capabilities. If, however, air be allowed to enter the results are altogether different; the fibres increase greatly in length, and often spores appear after forty-eight hours. The spores and fibres soon sink to the bottom of the glass; a watchglass was used. The other Bacteria, which the air had brought in, disappear, the characteristic smell appears, and the supernatant fluid becomes quite clear. Dilution of the fluid with a moderate amount of distilled or of spring water makes no evident difference, but a large quantity (*e.g.* twenty times as much) kills the *Bacilli*. Dampness, then, such as that to which either a body killed by splenic fever is exposed when buried to some depth, or left in fields, stables, or skinning yards, or the excreta of some sick animal are exposed, does no harm to the Bacilli, while it hinders the evaporation of the nutritious fluids in which the Bacillus has done its harmful work. Further, it is certain, from repeated experiments, that mice injected with a fluid rich in *Bacilli anthracis* die after twenty-four hours, while a fluid which contains but few spores is quite as successful in three or four days. Let only spores be formed, and specimens of dried Bacilli will be as fatal four years after, as ever they were; but the fibres will not retain their activity for more than five weeks. To these facts, thus rapidly recapitulated, let it be added that neither Koch nor

Cohn succeeded in producing splenic fever with any other species of *Bacillus*.

That *Bacillus anthracis* can produce splenic fever when injected into the circulating nutrition of the body is now abundantly clear. In addition to this, Koch tried whether the digestive or respiratory organs could be made the means of poisoning by this form. Mice and rabbits both ate either form of this species with impunity. As to the results of the inspiration of them, no satisfactory experiments were made.

The results of Branell[1] on the influence of the filtering action of the placenta were confirmed. To see how soon the poison took effect, nine mice were simultaneously injected with it, and examined after two, four, six, eight, ten, twelve, fourteen, and sixteen hours respectively. No *Bacilli* were found in the first six; the spleen alone of the seventh was affected; in the eighth this organ was enlarged, and the *Bacilli* more numerous. The ninth mouse died after seventeen hours of the disease, which was accompanied by its characteristic symptoms.

Two dogs, one partridge, and one sparrow, were injected with the poison, but no splenic fever ensued in these experiments; frogs also are not poisoned by the injection of fibres or spores of Bacilli. Koch describes, however, the changes which took place, when a piece of spleen which contained them was placed under the skin; but I do not think that I should be justified in detailing the facts here.

4. To fully know the ætiology of splenic fever, we must know much more than we do now. Can it be that ruminating animals cannot eat the spores with impunity as rodents can? Why is it that these larger animals take days to die while mice die in thirty hours? What are the various influences exerted by different degrees of temperature, depth of sepulture, humidity of soil, in the formation of the spores? Yet it is a subject for congratulation that Koch has so distinctly shown that the fibres, as compared with the spores, are comparatively harmless; let them remain dry for years, in decomposing fluids for months, be repeatedly dried and as often wetted, still do the spores retain their baneful influence on living animal fluids. A wound, however slight, is sufficiently large to allow them to enter. Use cotton wool to soothe a burn, and perhaps you are applying yourself the seeds of the disease that will kill you; bathe in a stream in which they are resting, and a scratch will offer them a way into your system. So much is clear; quite as clear, unfortunately, is the enormous extent of their ravages; in one small Prussian district £9000 was lost by the death of sheep from this disease; in three years the district of Novgorod lost 56,000

[1] Cf. 'Quart. Jour. Mic. Sci.,' July, 1876, p. 274.

horses and cattle and 528 human beings. The ordinary remedy has been to bury the victims deep in the earth, but Oemler has reduced the loss of his sheep from 21 per cent. per annum to 2 per cent. by forbidding the burial of the victims in fields and meadows.

Koch thinks that the best way to rid ourselves of this "destroying angel" is to utterly destroy all substances which contain Bacilli, but fears that it is impossible to adopt so radical a measure; he thinks that much might be done by placing all affected bodies in a dry pit to which air could not enter, and at so great a depth as to have a temperature always lower than 15° C.

Prophylactic measures are to be especially directed against sheep, as it is in them only that the disease is continuous; in the other cattle it appears only at intervals.

The concluding section of the paper draws attention to the similarity in conditions between this splenic fever and cholera and typhus, and expresses the hope that these two diseases may, with the advance of knowledge, be brought more fully under man's control.—F. Jeffrey Bell, Magdalen College, Oxford.

NOTES AND MEMORANDA.

Discovery of Nuclei in Foraminifera.—In a previous communication[1] on *Quinquiloculina fusca* (Brady), forming a part of his valuable series of "Rhizopodstudien," Professor Eilhard Schulze already shadowed out his extremely interesting and unexpected discovery of a nucleus in Foraminifera, and in a recent memoir he confirms and gives the enlarged details of his remarkable discovery.[2] It is highly interesting that, simultaneously and independently, the same discovery has likewise been made by Professor Hertwig,[3] as to which see below.

Leaving aside the baseless views of the older authors, such as D'Orbigny and Ehrenberg, who ascribed to the sarcode body-mass of the Foraminifera a high organisation, it is well known that, from Dujardin (the first to correctly appreciate the real simplicity of their structure) onwards, through a long series of years, even to Haeckel in his 'Gastræa-Theorie,' this group of Rhizopoda has been regarded as destitute of nucleus—the body-mass apart from the shells, in fact, but a simple single cytode or an aggregate of cytodes. Hence the interest and value of the surprising announcement made by these independent observers.

That this important element in the organization should have so long eluded observation is, perhaps, not at all surprising when one considers the many difficulties in the way of its perception presented by the shell (perfect or broken), the numerous granules of varied nature, oily and pigment, food particles, &c., not to speak of the density and opacity of the sarcode-mass itself.

At the same time it is remarkable that the naturalist on board H.M.S. Challenger, who specially studied the pelagic Foraminifera, should have failed to detect it when devoting so much time and attention to these organisms.

It was only by the observation of very small species with a delicate pellucid shell, and by application of acids to the

[1] Schultze's 'Archiv für Mikr. Anatomie,' Bd. xi, p. 136.
[2] 'Archiv f. Mikr. Anat.,' Bd. xiii, p. 9, t. 2, 3.
[3] 'Jenaisch Zeitschrift,' Bd. x, p. 41.

larger, in order to deprive them of the calcareous coating, and by the use of staining media, that Professor Schulze succeeded in demonstrating the existence of the nucleus.

In *Entosolenia globosa* (Williamson) the author found a combination of several conditions which rendered it a favourable object for study in this regard. Its ovate or elongate calcareous shell, deeply invaginated at one end, is hyaline, delicate, and smooth, and perforated by extremely fine pores; the body-mass usually quite or almost quite fills the cavity of the shell, though it can become reduced to a ball lying at the "posterior" end of the shell, such seemingly due to diminished nutriment. In the finely granular sarcode body-mass there occur embedded numerous strongly refractive, probably oleaginous, partly colourless, partly brownish roundish corpuscles, amongst which, towards the posterior end, the author could see even in the living example a distinctly marked, clear, globular body. That this was a corpuscle and not a vacuole or a granuleless spot in the sarcode was concluded from the constancy of its position and occurrence, as well as from the sharpness of its contour. Upon application during observation of dilute acetic or pyroligneous acid, the pores in the shell became at first more evident, then the shell became dissolved almost completely, and the granules embedded in the sarcode became so nearly deprived of all colour, that this now finely granular body stood out distinctly, as against its pale environment, and with a sharply marked contour, as an indubitable *cell-nucleus*.

But in the many-chambered calcareous Foraminifera the demonstration of the nucleus was accompanied by greater difficulty.

For several reasons the author chose *Polystomella striato-punctata* as the starting-point of the research: first, the readiness with which he could obtain it in different conditions; secondly, its regular structure was in favour of its study; thirdly, its shell was of comparatively small mass, and less troublesome to eliminate by means of acids; and lastly, he wished to study this form owing to its having been so largely the subject of research by preceding observers.

The arrangement and figure of the successive "chambers," and the finger-like conjoining processes are best seen in the sarcode-mass after removal of the calcareous shell. Athough Max Schultze first experimented in this way he did not appear to have detected the mutual bridge-like connection of the body-segments belonging to each chamber, but, on

the other hand, considered them as isolated. Carpenter (1862) was the first to discover these. After some details as to the number and arrangement of these sarcode processes which the author found to be of a more hyaline and less granular character than the rest of the sarcode-body, as well as more prone to imbibe staining fluids, he proceeds to describe his experiments in order to test the presence of a nucleus.

He first directed his attention to the median primary chamber, distinguished from the rest by its globular figure, but in it he never found by any method a nucleus or any body at all like it; sometimes, indeed, a few clear round spots could be seen, but pressure constantly proved these were merely drops of probably oleaginous nature, and without any wall; sometimes they could not be seen. Almost giving up the research in despair, he was much surprised one day, on looking at a specimen whence the shell had been removed, to notice a spot in one of the segments about midway of a different aspect. He then stained the whole object in a decoction of logwood, and in order to render the preparation clear, then applied a dilute ammoniacal solution. To his great delight he now saw at the previously mentioned spot, lying in the now clear, blue, granular sarcode, a violet-coloured globular body (0·056 mm. in diameter) with a distinct, thick, outer membrane and clear contents, in which could be recognised several strongly refractive elliptic or roundish structures of different sizes (whether to be regarded as *nucleoli*, or as produced by the treatment, the author leaves undetermined)—in a word, *a nucleus of almost typical structure.* Treating a great number of Polystomella forms in the same way he always arrived at the same result though with some modification.

Ordinarily in each Polystomella but *one* such nucleus was to be found, and this, indeed, always in the middle of one of the middle segments; in rare cases he found *two* nuclei occurring in adjoining segments; only once did he see the two nuclei separated by a segment without any nucleus; and once he saw *three* nuclei in one animal—two in immediate sequence, and separated from the third by a segment. The nucleus in older examples occupies some one (or two) of the middle third of the whole number of chambers; but in very young forms (4-10 chambers) he found the nucleus far behind, say in the second chamber. Sometimes, indeed, the nucleus was not confined to a single chamber, but one part of it in one, the other in the adjoining chamber; in such cases the segments remained hanging together by a

narrow isthmus, occupying one of the mutual communications. One portion of such a nucleus might be sometimes very small as compared to the other, so much so as to be reduced to a mere tip. From this circumstance the author regards a passage of the nucleus from one chamber to another by means of the connecting canals as probable, and the disturbance of the normally globular figure to be due to the constriction caused by the narrowness of the passage.

The author found afterwards a similar nucleus in a Rotalina.

Whilst admitting that the foregoing observations do not as yet prove *all* Foraminifera to be nucleated, the author still would suggest the likelihood that they really are so. From the fact that the whole of the soft body of a many-chambered Polystomella or Rotalina normally has but a single nucleus, it follows that the whole animal has but the value of a *single cell*, and the old question as to whether the Polythalamia are to be regarded as single animals or colonies of animals is disposed of, as the Foraminifera at large (admitting possible exceptions) must be regarded as *unicellular animals*.

Subsequent to his study of the freshwater Monothalmia, Hertwig turned his attention to the marine Mono- and Polythalamia, with the view of investigating their probable relations to the former. Both groups naturally appeared to him to possess, on the whole, great affinity, whilst certain of the characters relied upon by most naturalists in recent times, as calling for their separation, seemed to him not to possess so broad a systematic importance, nor to be so comprehensive as was usually assumed, such as the characters of the pseudopodia, or the distinction between non-contractile vacuoles and contractile vesicles. He had, therefore, come to the conclusion that the only character left to systematically separate the freshwater Monothalamia from the Foraminifera was the absence of a nucleus in the latter and the presence of this important structure in the former. For if, as had been generally assumed, the Foraminifera represented only an undifferentiated, non-nucleated, test-bearing protoplasmic mass, then, in a histological point of view, they could only be regarded as *cytodes*, whilst the freshwater forms would possess the morphological value of one or more *cells;* the Foraminifera would, therefore, come more close to Haeckel's Monera.

Max Schultze was the only observer who had afforded us a knowledge of the structure of the soft body, the researches

of others being mainly confined to the shells. Although M. Schultze was of opinion that, on the whole, the Foraminifera were without nucleus, still in *Rotalia veneta* he described a clear body, which was rendered more distinct on the application of acetic acid, and which he was inclined to regard as a nucleus, though unable to study it more exactly. He observed something similar, too, in an example of *Textilaria picta*, in which he succeeded "in isolating from the two last chambers a nucleus-like structure." Also he had described nuclei in *Gromia oviformis*.

Under the circumstances of the doubt in which the question was involved Hertwig availed himself of the opportunity of a visit to Heligoland to submit living Foraminifera to a renewed study, and he also obtained from Professor Haeckel examples from the Mediterranean sea.

But he soon found out that no definite result was to be gained by the examination of only fresh specimens, so he applied himself to the use of reagents. He found that acetic acid, employed by Max Schultze, was of no service: it only coagulated the substance, and rendered the object too dark. Better results were obtained by the application of dilute solution of chromic acid; in it the protoplasm swelled and became partly extruded from the shell, remaining tolerably transparent; but then a coagulation set in, darkening the preparation, accompanied, indeed, by a bleaching-out of the brown pigment; but as regards the coagulation, the chromic acid was no improvement on the acetic acid. In most cases, however, it sufficed to render the nuclei evident; in others, again, he had to take refuge in staining; for this purpose he used Beale's carmine fluid. By its application he obtained favorable results in preparations which had lain for a day in chromic acid, which had then been washed out by frequent renewal of the water for several hours.

Young examples of Miliolæ offered the most conclusive results. The youngest were single chambered in the fresh state; in spite of the pellucid character of the shell, he could not discover a nucleus with any certainty; he could only distinguish a homogeneous, nucleus-like spot. This, however, coagulated on application of chromic acid into a sharply-contoured, minute circle (0·01 mm. in diameter), disclosing within a sharply-contoured little body (0·004 mm. in diameter). Still more distinctly did this structure come out with "Beale's fluid," the inner body assuming a ruby red. Whether this structure represents a nucleus differentiated into nucleolus and nuclear membrane, or (in the fresh state) a homogeneous nucleus, merely assuming, owing to

irregular coagulation of its substance, such an appearance, the author leaves undecided; but he thinks the latter improbable, and leans to the view that it coincides in structure with the nucleus of the freshwater Rhizopoda.

In the three-chambered Miliolæ, in one case, he saw only *one* nucleus; in two others two were present; in a four-chambered example he found seven, three appertaining to the first chamber, one to the second, and three to the third. They were all alike, except that one was smaller than the rest.

In large examples he was mostly unsuccessful in meeting with nuclei, probably due to the density with which the parenchyma became filled with foreign bodies.

The second Foraminifer in which the author succeeded in demonstrating the nucleus belonged to the Perforata—a little Rotalia, agreeing with M. Schultze's figure of *R. veneta*, the chambers arranged in a flat spiral, the shell-opening of considerable size, the protoplasm of brownish-granular and opaque (except in the last chambers), the pseudopodia richly granular, not very long, only slightly branched, and still more rarely inosculating. But rarely in the living organism could the author recognise the indication of the nucleus in the form of a clear spot of brownish granular protoplasm; he succeeded best in young single-chambered examples; in these he found a single round nucleus, and under chromic acid he could see the nucleolus. By the aid of carmine solution he found that, with the growth, an increase in number of the nuclei took place; thus, in a four-chambered Rotalia at one time four, at another three, nuclei; in a three-chambered, three nuclei; whilst in other cases, in many-chambered individuals, but one nucleus was recognisable. Still, it does not at all follow that more might not have been present.

On two occasions the author found in his collecting bottle little bodies, which he took, with the unassisted eye, for young Rotaliæ; under the microscope these proved to be clusters of thirty to forty young three-chambered individuals. In one case the connection of these was due to a common protoplasmic envelope, from which tufts of pseudopodia radiated in such abundance that they were perceptible to the unassisted eye. They thus resembled a colony of the freshwater *Microgromia socialis*. The shell was comparatively thick, and had a rough aspect, some ten to fifteen minute foramina disposed irregularly on the surface. The protoplasm filled the two first chambers completely, the third only partially, the pigment granules more copious in the first. The author could see nuclei herein only by the help of reagents. In most cases chromic acid sufficed, but the carmine fluid

answered still better. A nucleolus did not appear to exist, but rather the nucleus seemed to form a homogeneous mass; but its unequal coagulation might present a nucleolus-like aspect. There was only one nucleus, and that in the primary chamber.

We have manifestly here the starting-point of the reproductive process observed by Max Schultze and others. It consists essentially in this, that within the mother-shell, in a manner not yet more closely observed, daughter individuals are developed, surrounded by a proper shell. In Miliola and Nonionina the daughter individuals are one-chambered, in Rotalia—from the commencement—three-chambered. It is of interest to note that in both cases the young individuals are single-nucleated—are *unicellular*—regarding the nucleus as the centre of individuality of the cell.

From his experience, so remarkably confirmed by that of Professor Eilh. Schulze, then, the author feels justified in drawing the conclusion that all the Foraminifera—Imperforata and Perforata—are nucleated, thus removing the only ground of systematic separation of the Foraminifera from the Monothalamia, and both groups must be united in a single Class. The freshwater Monothalamia would, of course, most approach the single-chambered Gromia, Cornuspiræ, &c.

For such a Class the author urges the names "Polythalamia" and "Foraminifera," being applicable to only a part of the series, not to the whole, are manifestly each respectively unsuitable.

More appropriate would be Haeckel's term "Acytaria;" Haeckel, however, so designates the Foraminifera only, to the exclusion of the freshwater Monothalamia, which latter he includes under his Lepamœbæ. As regards its signification, the term might certainly be extended to embrace the Monothalamia; but Haeckel employed the name to distinguish Radiolaria without a central capsule from those furnished therewith. Now, there are whole series of sarcode organisms agreeing in this respect with Foraminifera which, so far as that is concerned, might be relegated to the Acytaria. The designation is, therefore, defective. For this reason the author proposes to call the class "Thalamophora," in allusion to their all-pervading characteristic.

As regards the subdivision of the Thalamophora, the author points out that two courses are open: either we might make the arrangement of the chambers the principle of division, or the finer structure of the chambers; in the one case we should subdivide them into Mono- and Polythalamia, after Max Schultze; or, in the other case, into Imperforata or

PROCEEDINGS OF SOCIETIES.

Dublin Microscopical Club.

13*th July*, 1876.

Fructification of Preissia commutata, exhibited.—Dr. Moore showed a preparation of the fructification of *Preissia commutata*.

On Stauroneis phyllodes (Ehrenb.), Kütz., Rabenh.—Rev. E. O'Meara exhibited a form of Stauroneis in external aspect strongly resembling that figured by Kützing and Rabenhorst as *Stauroneis phyllodes*, and by those writers attributed to Ehrenberg. No feature of the species except the external outline is noted by those authors, and if the form under consideration be identical, therewith, as Mr. O'Meara seemed inclined to think, the following particulars are to be superadded to the vague description: Transverse striæ fine, slightly radiate, easily resolvable into moniliform dots. The only habitat assigned by Kützing and Rabenhorst to this species is South America; Ralfs, in 'Pritchard's Infusoria,' mentions China as the only other place in which it had been found. It is, therefore, interesting to find it occur in Ireland, the only locality (as yet) being Lough Mask, near Tourmakeady, Co. Mayo.

Cosmarium cyclicum, Lundell, *also Cosm. tetragonum*, Näg., *form (so-called by)*, Lundell, *exhibited.*—Mr. Crowe showed *Cosmarium cyclicum*, Lundell, or rather, more probably, that form of it recorded by Reinsch; the present examples were taken by Mr. Crowe on the occasion of a tour, along with Mr. Archer, in Scotland. This is an extremely rare species in Ireland; it has occurred as yet once at "Callery Bog," once at "Rocky Valley," both near Bray, and some half dozen specimens at "Toole's Rocks," Co. Wicklow.

Mr. Archer showed also Lundell's so-called form of *Cosm. tetragonum*, Näg., taken also in Scotland on the same occasion. This, too, is an extremely rare species in Ireland, occurring as yet extremely sparsely at that very restricted, but from time to time by no means poor, little locality in the "Rocky Valley;" also at "Toole's Rocks," and once in Connemara. The Irish and the Scottish examples accord in every respect and detail absolutely, and they are, doubtless, identical with Lundell's species; but, although Mr. Archer did not know Nägeli's form, ours did not accord therewith, at least by any means in the way that the Irish and Scottish examples did with each other and with Lun-

dell's; hence Mr. Archer was inclined to suppose this would turn out a distinct species from Nägeli's.

New Species of Staurastrum, exhibited.—Mr. Archer further showed examples of a large and rather striking new species of *Staurastrum*, taken on the same occasion in Scotland, in the famous "Pass of Glencoe." This *somewhat* resembled *Staurastrum Pringsheimii*, Reinsch, *plus* three usually (sometimes two only, sometimes four, or even five), long, stout, subulate spines at each angle; but it further differed, amongst other points, from that species in that the spines on the surface were not very numerous and indefinite in number, but were few and definite. Across the broadly elliptico-fusiform semicell, on each front surface, near the base, runs a series of four spines, a marginal series of five above this; on the upper surface, seen in end view, occur fifteen spines—two, one behind the other, obliquely pointing towards each of the three angles, and a series of three on each side between each of the innermost of the pairs at the angles. When the angles bear two or three of the long and rather stout spines (as described) they are usually superposed, and one only usually presents itself to view in the end view, though they may occasionally somewhat diverge; but in the rare cases, when there are more than three angular spines, they seem to form an obliquely-radiating group (somewhat comparable to the mode of arrangement of the feathers of a "shuttlecock").

Attention to these features would, Mr. Archer thought, suffice for the present to distinguish this species, which is decidedly most distinct. He would have great pleasure in naming it *Staurastrum Royanum*, in compliment to his esteemed friend and valued correspondent, Mr. John Roy, of Aberdeen, to whose acute judgment and hearty co-operation he had for some time been so greatly indebted in their joint effort to "work out" this family.

A new (Young's) Section-cutting Razor.—Mr. B. Wills Richardson exhibited a section-cutting razor, of large size, recently brought out by Mr. Young, the surgical instrument maker, of North Bridge, Edinburgh. The cutting edge of this instrument is $4\frac{1}{2}''$ in length, which is sufficient for the cutting of a large number of structures at *one sweep of the blade;* thus, it is long enough for the complete section of the spinal cord at one cut. He (Mr. Richardson) might mention that he recently made with it some very even sections of one lateral half of the pons varolii. The cutting edge of a knife of the razor form is less liable to accident than a fixed-handled blade, requiring a case for its protection, and is necessarily more expensive.

Occurrence in Scotland of Euglypha tincta, Quadrula irregularis, and Ditrema flavum, Archer.—Mr. Archer desired to mention that he had taken in Scotland the three new and seemingly rare Rhizopoda lately shown by him to the Club—*Euglypha tincta*, *Quadrula irregularis*, and the new yellow Amphistomatous form, with smooth and naked test, shown 17th February last. This last he would name *Ditrema flavum*. Of it he had, indeed, seen but a

single Scottish example, though he had now found it very sparingly in collections made from the south and west of Ireland. The Scottish and Irish specimens are absolutely alike.

17*th August*, 1876.

Somewhat doubtful form of Stauroneis phyllodes, exhibited.—Rev. Eugene O'Meara showed a form of Stauroneis from Lough Mask, which at first sight might be considered as undescribed, but, on more careful investigation, he was disposed to regard it as identical with that exhibited by him at the previous meeting, differing only in having the striæ somewhat closer and finer.

Exceptionally high-coloured brownish-crimson example of Hypnum revolvens.—Mr. Pim showed *Hypnum revolvens* from near the base of Carn Tual Mountain, Killarney, remarkable as being very richly coloured a deep brownish-crimson.

Structure of spine of Phyllacanthus gigantea.—Mr. Mackintosh exhibited a cross-section through the milled ring of the spine of *Phyllacanthus gigantea*, A. Agass., and drew attention to its very slight development. The typical structure (shown for comparison *Centrostephanus Rodgersii*, A. Agass.) consists of a number of separate segments with a somewhat petaloid arrangement of their reticular tissue; but in the specimen under notice this was entirely absent, the peripheral part of the section being formed by a network whose interspaces were less regularly arranged than in the part nearer the centre. The feeble development of the milled ring seems to be the rule amongst the Cidaridæ.

Mesentery of Echinus esculentus, Linn., *exhibited.*—Mr. Booker exhibited a portion of the mesentery of *Echinus esculentus*, Linn., which contained a number of minute rounded cells (?) with reddish-yellow pigment, and also numerous calcareous spicules shaped like the letter C, with a nodular thickening in the middle of the curve, somewhat like, but easily distinguishable from, those figured by C. Stewart ('Trans. Linn. Soc.,' vol. xxv), from the ambulacral tube of Echinometra.

New species of Oocystis, Näg.—Mr. Archer showed some recent examples (none mounted could possibly present the same beauty) of a unicellular algal form referable to Alex. Braun's genus Oocys-
tis, and, doubtless, forming a new species, at once distingui-
by its large size, the broadly elliptic cells being in lengt
0·0027" in breadth 0·0020 to 0·0024," thus
than broad. The cell-wall is, by comp
the somewhat nodular little thickening
in other species); the chlorophyll-granul
these were not too dense, could be
beautifully and curiously regul
"meshes" or interspaces of th
bare of them. Mr. Arch
the expanded mother-
in *Oocystis Naegelii*
viduals the conten

arrangements lost, or rather, perhaps, more properly speaking, the interspaces become clothed with chlorophyll-granules. At first glance this might be mistaken, under a low power, for that small form of *Eremosphæra viridis*, de Bary, which originates when the individuals of the ordinary large form produce simultaneously four in place of two daughter-cells; but the evident elliptic figure and the thickened poles, as well as the different arrangement of the chlorophyll-contents, would, on closer inspection, at once distinguish them. Mr. Archer drew attention to the seemingly curious very great expansion of the wall of the mother-cell, almost looking as if in anticipation, rather than as in consequence of the growth of a young "brood" of two, four, eight, or sixteen daughter-cells; so much so that it almost had the aspect of a fresh growth rather than that of a mere swelling-up of the old membrane. The genus Oocystis, Al. Braun, comes very near Nephrocytium, Näg., the seemingly only very tangible distinction (it is a very constant one, at the least) being the reniform (not elliptic) cells in the latter genus; but as forms merely of more or less frequent occurrence, those referred to both the genera are, indeed, very distinct and constant things. There is a probably more distant affinity, too, to Polyedrium, Näg., of which genus Wittrock has described a large form (occurring also in Ireland), and called it *Polyedrum gigas*, from its comparatively great size. For the same reason this form of Oocystis might stand as *Oocystis gigas*.

The unlike Zygospores of two minute smooth closely resembling Cosmaria, exhibited, proving their specific distinctness, the puzzling resemblance of the forms themselves notwithstanding.—Mr. Archer showed two closely resembling minute smooth Cosmaria, both of which would be described as possessing elliptic semicells, the differences in the contours of the two forms being so slight that no doubt many might say it was but straining to regard them as distinct species. Still, on close examination, one could readily see that, besides size, there were really very appreciable, if but comparatively slight, distinction in their outlines. But all doubt as to their distinctness would seem to be set aside by the marked differences in their zygospores—the smaller had a quite smooth, dark brown orbicular zygospore, the other a larger colourless spore, beset with tapering subacute spines. Mr. Archer merely now brought forward these two forms, which he had never before exhibited, as a very pretty instance of the wonderful inherent specialities bound up with the individual entities amongst these algæ.

Encysted state of Heterophrys Fockii, Arch. = *Sphærastrum conglobatum*, Greeff, *exhibited.*—Mr. Archer showed an example of the encysted state of the not uncommon Heliozoan he had called *Heterophrys Fockii*, most probably identical with *Sphærastrum conglobatum*, Greeff, the inner body being surrounded by a doubly-contoured cyst, the outer region excluded and appearing

almost like a hyaline, much crumpled membrane, having lost its granular aspect.

21*st September*, 1876.

Sections of Leptogium tremelloides, exhibited.—Mr. Pim showed examples and some instructive transverse sections of *Leptogium tremelloides* as identified by Rev. W. A. Leighton. The preparation showed the upper and lower cortical layer to consist of, in this aspect, nearly square cells between which were the phycochromaceous more or less moniliform strings of gonidia and the hyphæ. Viewed vertically the cells of the cortex were of irregular figure and closely set. One section passed through what was apparently an apothecium from which the asci had fallen.

Structure of Sheath of Spine of Goniocidaris geranioides, Lamk. —Mr. Mackintosh showed a cross-section of the spine of *Goniocidaris geranioides*, Lamk., and drew attention to the nature of the external sheath, which is composed of reticulated tissue, with very wide interspaces, instead of the ordinary solid calcification with simple tubes which occurs in all the Cidaridæ, as far as he had observed. This peculiarity does not seem to be shared by the species of Goniocidaris.

Undescribed Species of Craspedodiscus.—Rev. E. O'Meara showed a diatomaceous form appertaining to the genus Craspedodiscus, which he considered as yet undescribed. It differs from *Craspedodiscus coscinodiscus* in having the areoles of the interior portion of the disc much larger than in the marginal portion. The example was found in fossil earth from Delaware, Maryland, U.S.A. In case the form is not described, Mr. O'Meara would suggest the specific name of *Marylandicus*.

A Puzzling Desmidian form.—Mr. Archer showed examples of a seemingly unicellular (non-filamentous) algal form, not unlike a joint of *Gonatozygon Brébissonii*, but smooth, not asperate. To a great extent it had the aspect of yet another companion-form for that named *Closterium obtusum* by de Brébisson. His friend Mr. Roy, of Aberdeen, to whom he had submitted fresh specimens, seemed to regard it as a very distinct thing indeed, but Mr. Archer must say he still remains in considerable hesitation. Perhaps more of it on a future occasion.

MEMOIRS.

RÉSUMÉ *of* RECENT CONTRIBUTIONS *to our* KNOWLEDGE *of* "FRESHWATER RHIZOPODA." Part IV. Compiled by WM. ARCHER, F.R.S. (With Plate VIII.)

MONOTHALAMIA (*Monostomata*) LOBOSA (*continued*).

Pseudochlamys patella, Clap. et Lachmann[1] = *Amphizonella flava*, Greeff[2] (Pl. VIII, figs. 1—3).

THERE can be little doubt that the not uncommon rhizopod identified by Hertwig and Lesser as above is indeed one and the same with Claparède and Lachmann's form, and, with not less doubt, is also identical with that erroneously called *Amphizonella flava* by Greeff.[3]

The test possesses ordinarily a hollow, dorsally convex discoid figure, somewhat like *Arcella vulgaris*, but a great deal smaller, its upper or convex side equally and evenly arched. Its colour at the middle is of a brownish yellow (resembling in tint that of the contents of many diatoms) mostly gradually fading off to the margins, which may be quite colourless; but I have myself frequently seen examples in which the change was abrupt and quite irregular. This colour resides in the test itself. The median portion of the test is thicker, and it gradually thins off to the margin. In many specimens an arcella-like facetting or punctate appearance can be readily made out, gradually disappearing towards the margin; but in many others this cannot be at all discovered when it has a more or less smooth, but not a glossy, aspect. I believe the appearance of "facetting" or "shagreening" is due to little rounded, closely posed, scattered scrobiculi.

Ordinarily the test appears of watch-glass shape, that is, deeply concave on one side and correspondingly convex on the other; the outer or convex side it is which bears the

[1] Claparède and Lachmann, 'Etudes sur les Infusoires et les Rhizopodes,' p. 443.

[2] L. c. p. 100, t. iii, f. 1.

[3] Greeff, 'Archiv. f. Mikr. Anat.,' Bd. II, p. 329, t. xviii, f. 19.

markings. In empty tests (much more frequently met with, so far as I can see, than still retaining the sarcode body) this really appears to me all that is left—at least, all that can be seen. But in the living examples, as Hertwig and Lesser were the first to point out, the concave side is closed, all but a median central opening, by a delicate and hyaline continuation of the test completing the external resemblance to an Arcella. Unlike Arcella, however, not only (when the rhizopod is living) this lower part of the test appears capable of undergoing alteration of figure—sometimes drawn in at the middle, sometimes prominent (like, as say Hertwig and Lesser, "the stomach of a Medusa"), but also the whole test can assume various, by no means inconsiderable, alterations of figure, even so much that the two opposite parts of the periphery of the disc of the test may become bent downwards or doubled towards each other so as almost to touch. When in this temporary position such an example would very much resemble Greeff's figure of the supposed form of "Amphizonella" which he called "*A. flava.*" It almost seems as if the stolon-like sarcode processes passing from the body-mass, and inwardly attached to the angle of the test, acted as "muscles" in causing its contraction, and that on the withdrawal of the force it recovers its normal form by virtue of its own elasticity.

The body-mass does not fill the test, but sends off several of those "stolon-like" sarcode processes to the (inner side, of course, of the) periphery of the test, similar to Arcella and Difflugia. The protoplasm is minutely granular, and (near the margin) usually show several contractile vacuoles and a median nucleus. Hertwig and Lesser record that between the test and the body-mass occur some coarsely granular pigment of the colour of "diatomin." Without venturing to contradict so accurate observers, I would myself merely suggest that this colour seems to reside wholly in the test; it is quite as deep, and even brighter in empty tests, as when the organism is living.

I have several times watched a living example with the hope of seeing the projection of the finger-like pseudopodia described by Hertwig and Lesser, but have never seen this, possibly due to their being very short, that is, not extending beyond the periphery of the shell, as, indeed, those authors describe.

The only mode of reproduction observed by Hertwig and Lesser is by encysting, the body-mass becoming balled together into a spherical figure, the result of which they could not follow out. I have also noticed an encysted state,

but the contents had not assumed a globular figure, but had become condensed in the "top" of the shell, and enclosed by a wall on the upper side adapted to the figure of its interior, and in the lower of equal convex figure, so that on the whole the "spore" (so to call it) had acquired the figure of a thick doubly convex lens. (See Plate VIII, fig. 3.)

As originally described by Claparède and Lachmann, the test was said to form a simple disc, capable, however, of altering its figure and becoming folded; thus, according to them, the concave or lower side of the test was wholly open.

Seeing the capacity for folding and unfolding, as well as the retraction and projection of the hyaline and delicate "lower" (oral) wall of the test, it is possible that a form which I have met with may but represent a phase of the same species. But whilst the test of the latter when empty and *dead* seems always to present a deep watch-glass-like figure (that is, when viewed laterally or from the edge, forming externally a broadly and equably rounded arch), the present, in the same condition (viewed also laterally), presents a figure not unlike that of a very shallow *hat* with a narrow *rim*, or that of a round "baking-dish"—the upper contour only gently convex, then suddenly depressed and again somewhat suddenly widening out to form the rim. The former, when viewed dorsally, shows the disc more or less gradually fading off in colour towards the periphery, or if the transition from coloured to hyaline be rather sudden, it is irregular, whilst in the latter the transition is always abrupt aud sharply limited, and circular in contour. In fact, the colour in the latter is restricted to the elevated portion, the border or rim (of the "hat" or "dish") being colourless and hyaline; hence in this "dorsal" view the median portion of the disc is often seen to be encircled by a tolerably sharp ring of higher colour, itself again immediately surrounded by the colourless rim, which fact is due to the observer seeing through a greater thickness of substance just at the place where the sudden descent of the contour from the slightly convex median disc takes place down to the outer hyaline border. I think this form also seems to be of somewhat smaller dimensions than the other; greatest diameter, 0·0015″, of the median coloured part of the disc (viewed dorsally) 0·0013″. If we may assume that, when the shell becomes abandoned by the living sarcode, and hence no longer acted upon by the locomotive or other movements of the organism, it then is unrestrictedly free to assume what may be called its normal

figure, it is possible we may justly enough regard the form here drawn attention to as specifically distinct from that of Claparède and Lachmann; but for the present I would not venture to pronounce any more decided opinion; it is quite possible it will be refound in the future by other better judges.

Pyxidicula operculata (Ehr.), = *Arcella patens* (Clap. et Lachm.[1]) Carter.[2]

This rhizopod, as described by Hertwig and Lesser, is furnished with a test, dorsally, of the form of a highly convex watch-glass, curved inwards below at the periphery all round, so as to leave a median pseudopodial opening; its colour of a brownish yellow, though sometimes colourless, and covered externally by irregularly scattered, very minute roughnesses ("von unregelmässig vertheilten feinsten Höckerchen bedeckt"); the pseudopodia (seldom, however, showing themselves) are conical, like those of an Arcella; one evident nucleus and a few contractile vacuoles are present.

This form I do not myself as yet know; its separation generically from *Pseudochlamys patella* seems to be based on its external "Höckerchen" or granulations as compared to the "shagreening" or scrobiculi (?) of the latter.

Hyalosphenia lata, Eilh. Schulze[3] (Pl. VIII, fig. 5).

Under the above name a lobose Monothalamian sarcodine is recorded by Professor E. Schulze, which he relegates to a genus founded by Stein for a form discovered by him near Prague. There appears to be no figure extant of Stein's original species, *Hyalosphenia cuneata*, Stein. It is thus described[4] (as quoted by Schulze): "Test oval, much flattened in front in a cuneiform manner, truncate at the frontal end, without lip-like margins, everywhere glassy, pellucid, and colourless, without any trace of polygonal impressions. From the narrow opening always but a single finger-like pseudopodium is projected. The animal can abruptly and quickly become retracted to the bottom of the test, whereby all connection with the orifice of the test is done away with."

The foregoing is sufficiently vague, both as regards the form of the test or the nature of the body. Assuming it to

[1] Claparède and Lachmann, 'Etudes,' &c., p. 446.
[2] Carter, 'Ann. Nat. Hist.,' vol. iii, p. 31.
[3] Schulze, in 'Schultze's Archiv f. Mikr. Anatomie,' Bd. XI, p. 335, t. xviii, f. 15—18.
[4] Stein, 'Sitzungsberichte der Wissench.,' Jan., 1875.

have a nucleus, and knowing its pseudopodium to be finger-like—that is, "lobose"—we would have before us, as it were, a *Difflugia*, but with a test not only devoid of any reticulated marking or special structure, but also without the superposition of any foreign objects (arenaceous particles, &c.). Possibly a "Difflugian" of such a character would really deserve to be kept apart, as well from such a type as Quadrula, on the one hand, as from such as (say) *Difflugia pyriformis* or *D. oblonga* on the other; but in that case it would become a question as to how we should deal with those Difflugian forms with a kind of partially hyaline and corrugated or more or less reticulated appearance of the test (not absolutely pellucid, smooth, homogeneous, and "structureless," as in Hyalosphenia); such, for instance, as *Difflugia triangulata*, Lang (a most marked and decided species); *Difflugia carinata*, Archer, &c.; at any rate, although I have not, I believe, seen either form, I should venture *ad interim* to think the genus Hyalosphenia is justifiable.

Schulze's new species, too, has a thin, membranous, pellucid, and quite structureless chitinoid test; but it is pyriform, laterally compressed, at the narrow "oral" end abruptly truncate; its length 0·06 mm., greatest breadth 0·035 mm., scarcely quarter this breadth at the "mouth," greatest thickness 0·015 mm.; end view (seen from behind) elliptic, with the apices somewhat produced and broadly rounded; contour of mouth (seen from the front) narrow elliptic; its margin very slightly thickened. The body-mass does not completely fill the test, to which it is united by a number of stolon-like sarcodic processes, as in Quadrula, Pseudochlamys, and others: at the mouth it is in close connection with the test; the author never perceived, unlike the form described by Stein, any sudden retraction of the body into the interior of the test. The homogeneous clear plasma is pervaded by many pretty nearly equal-sized pale globules or granules; a globular nucleus is posed towards the posterior end, enclosing a few comparatively large dark-looking globular nucleoli, whose number may reach as many as six, or even more. Beside and somewhat in front of the nucleus occur usually two pulsating vacuoles. Any food materials lie in the median region of the body in front of the nucleus. The pseudopodia are finger-like, ordinarily only one, but sometimes two or three; they are permeated by extremely minute granules, of which a movement could be seen, especially in the axial region of the longer pseudopodia.

Quadrula symmetrica, Eilh. Schulze,[1] = *Difflugia symmetrica* (Wallich), (Pl. VIII, fig. 6)

is a Difflugian form which, in my opinion, Prof. Schulze was amply justified in taking as the type of a distinct genus, the differential characters of course residing in the test, as the animal portion or sarcode body offers no very tangible distinction from an ordinary Difflugia; there are occult differences, no doubt, else how the wide distinction when "fully formed?" The first to recognise this species seems to have been Dr. Wallich;[2] I have myself met with the same form, though by no means frequently, in various collections, and would have proposed its being considered the type of a distinct genus, especially on my recently finding a further species of the same structure as regards the test. For I would quite agree with the view now expressed by Schulze that only Lobosa, whose habit is to build up or affix foreign particles, should be retained in the genus Difflugia proper. At the same time it is an open question whether all these which do so should be relegated thereto; as for instance the peculiar and remarkable seemingly unique structure of the test of the common form *Difflugia spiralis*, although it often appends externally arenaceous particles, would, I fancy, justify its separation.

In Quadrula the test is formed of hyaline angular plates, apposed laterally and in mutual contact. They are ordinarily square or slightly oblong, but occasionally in some parts of the test they may be triangular, trapezoid, or even more or less irregularly figured, this variation in shape from the square being in order to adapt themselves to the characteristic total figure of the test and so as to leave no mutual intervals or lacunæ. In *Quadrula symmetrica* the test is of a compressed pyriform figure, with straight longitudinal axis, and with a broad elongate neck abruptly but roundly truncated; the transverse view oval; the broad "mouth" offers two "lips" (on a line with the broader sides), each with a convex margin, between which on each side (on a line with the narrower sides of the test) is an intervening hollow. At the broader inflated portion of the test the hyaline component plates are larger and more regularly square in figure; on forming the neck or approaching thereto it is that they diminish in size or alter in figure according to the exigencies of the contour so as still to remain in mutual apposition and at same time build up the characteristic figure of the species.

[1] Schultze's 'Archiv f. Mikr. Anat.,' Bd. xi, p. 329, t. xviii, f. 1—6.
[2] 'Ann. Nat. Hist.,' vol. viii (1864), p. 815.

Normally they may be said to run in longitudinal and transverse series, but they may occasionally run obliquely, or even an abrupt alteration of arrangement may occur, yet on the whole all are nicely posed to produce the symmetrical characteristic external aggregate contour of the test. A greater disturbance of the symmetry of the plates may often take place close to the edge of the "mouth," where, whilst they become smaller in size, they also suffer greater alterations of individual figure so as to become adapted to the peculiar contour, as described, of the frontal opening, the extreme edge of which appears to form a thickened margin. These plates are not very firmly combined, a moderate pressure sometimes suffices to dislocate them, and in abandoned tests one sees often little accidental aggregations of these plates, lying often superposed.

The body-mass and its pseudopodia are like that of an ordinary Difflugia. It does not quite fill the test; often there proceed a few slender sarcode processes therefrom to the test, forming so many attachments; in the posterior end occurs a nucleus with nucleolus, and towards the anterior end may sometimes be seen a few pulsating vacuoles.

Quadrula irregularis, n.s., Archer.

Except in being smaller, corresponding to the smaller test, there is not any distinction to be drawn from the sarcode body, as just described, as regards the form I would here record under the foregoing name, its differences being in the size and figure of the test; still I would not be in the least disposed to regard it as but a *young* form of *Q. symmetrica.* I have taken this form from extremely remote localities, both in Ireland and Scotland, and ever presenting the same features, and I have likewise noticed a single example quite identical with the British specimens on a slide of Nordstedt's, the material having been collected in Italy, the Quadrula accidentally present, indeed, as the slide was put up for a Cosmarium. It is sometimes accompanied by *Q. symmetrica*, but more frequently presents itself alone; it must, however, be accounted rarer by a good deal than the typical species.

This form is smaller than *Q. symmetrica*, quite without any neck, the "mouth" being where a small chord seems, as it were, cut off the globular, or perhaps somewhat compressed test, nor are there any "lips" nor even any evident thickened margin; the mouth seems as it were but a cessation of the component plates, but on the whole subcircular in outline. As in the former, the typical form of the plates is square,

whilst at same time they are even more subject to variation in shape and size, and are often somewhat rudely applied and even in the living animal more prone to become dislocated. They sometimes show a thickened "frame-like" edge which forms a narrow rimlike border, or it may be so extended as to leave but a minute square in the middle, but mostly they are alike throughout. They mostly run in lines longitudinally (taking the "mouth" as the *anterior* end) and transversely at right angles, but sometimes obliquely; still the ordinary contour is ever maintained. This form sometimes showed a few spines comparable to those of a Euglypha, but this rarely; but I could not make out the place of origin of these, whether they occur between the plates (that is, of independent origin), or as processes given off from certain of them (which is more likely). This point would deserve attention should the spiniferous form again present itself.

Difflugia acropodia, Hertwig and Lesser.[1]

Under foregoing name the authors record a well-marked Difflugian of rounded figure which they say is not common (diam. 0·05 mm.). It consists of a homogeneous pellucid membrane, the foreign attached objects for the most part consist of quartz-granules, with sometimes a few diatomaceous frustules, mostly loosely fixed, that is, leaving considerable irregular intervals, though sometimes more crowded and completely covering the test. But the greatest distinction of the present from other species of Difflugia is in the form of the pseudopodia, which are not blunt finger-like prolongations, but form long more or less distinctly conical plates, running into variously lobed and subdivided shapes, always rather acutely pointed at the apices; sometimes one may run out long and comparatively thin (as it were subulate), almost resembling a pseudopodium of an Actinosphærium, but here the pseudopodia are always homogeneous, never granular. They fitfully branch, and on contact may occasionally anastomose, even as they ramify with the tendency to become flattened out, or two may appear to coalesce by the running up between of a membrane-like continuation of plasma, soon to be retracted or modified in contour, so fluent is the movement of this form and so manifold the changes of its pseudopodial region. Sometimes, indeed, a finger-like projection can be seen amongst those described, but the authors seem inclined to regard this rather as indications of

[1] Hertwig and Lesser, loc. cit., p. 117, t. ii, f. 6.

abnormal changes brought about by the gradual evaporation of the water during observation.

From this it will be seen that this remarkable form offers a peculiar exception to the general character of the Lobose pseudopodia. As well as thin and broad protoplasma-plates occur almost linear, branching and anastomosing processes, pointing to the pseudopodia of the truly "rhizopodous" forms.

But whilst this is so, I venture to think without myself knowing the form, but judging from the graphic figure, that this is an unmistakeably distinct species from every other, and whilst the resemblances pointed out no doubt are there, there is still *no identity* of any of the pseudopodia of this form (as depicted) with those of any other freshwater form.

Notwithstanding the apparently favorable conditions the authors were unable to gain any insight into the structure of the body-mass.

Monothalamia Rhizopoda.

Microgromia socialis (Arch.), Hertwig = *Gromia socialis* (Archer) (Pl. VIII, fig. 8).

This minute and interesting Monothalamian has been made the subject of a prolonged study, and of a most valuable memoir by Dr. Hertwig, too long, indeed, to do more than give a brief epitome of his results. It is long since I myself discovered my great and radical error in taking the great agglomerations or colonies, in which this species sometimes occurs in mutual combination, as representing an independent rhizopod of a different genus, but I do not see that I so greatly erred in referring the form to the genus Gromia; in fact, as I have mentioned, the tendency of observers in this field seems to me to be to make too many genera, at same time there is probably, as Hertwig considers, sufficient reason in the present instance to justify the step.

Hertwig points out that the smooth and pellucid test presents a bilateral symmetry owing to the slight diversion to one side of the prominent portion forming the very short necklike oral extremity, so that thus a left and right, a dorsal and a ventral, side may be distinguished, but so slight is this deviation that it might be readily overlooked, as indeed I formerly did. Viewed from an end the test appears circular. When forming a dense and large cluster (my supposed "Cystophrys") the constituent individuals of a group radiate, with the oral end inward and become seen with the rounded posterior end outward, which explains my original error of supposing I had before me a group of closed spherical "cells."

Hertwig announces that the hyaline smooth test does not become coloured either by iodine, nor by it along with sulphuric acid, and that it does not become altered under mineral acids or alkalies; but whether it contains any siliceous constituent he would leave undecided.

Not only is the test thus bilaterally symmetrical but the body-mass also; it is sharply contoured and of a "retort-shape," of which the "neck" passes out through the oral opening, broadening out there into contact with the test, the only place indeed where such occurs; from the necklike part are given off the pseudopodia (as originally correctly described by myself) and this portion, as in similar forms, Hertwig denominates the "pseudopodial stem."

Sometimes the body all but fills the test, sometimes it occupies only a small portion of the cavity—seemingly partly dependent on degree of nutrition, partly on reproductive conditions (as will be seen). Hertwig's description of the sarcode body and nucleus seems to agree with my own. A single or double contractile vesicle of variable size occurs in the anterior part of the body, the contractions very slow and uncertain.

The pseudopodia are also described by Hertwig pretty much as I did, with the exception, of course, that the complete fusion of these into a common matrix—the "Cystophrys state"—was wrongly interpreted by me; in this state they project around more or less irregularly from the common matrix, and the rarity of the mutual inosculation of the ultimate branches in this condition must be attributed solely to the radiating arrangement preventing their coming into mutual contact. But if they come into contact they will inosculate, and even whole bundles of them can exceptionally do so and form a long protoplasm-plate at one side; but usually, indeed, they are shorter in the Cystophrys-state than in the ordinary more or less isolated condition. Hertwig rightly states the current within the pseudopodia to be a very slow one, especially as compared to the vigorous flow in those of a *Gromia fluviatilis*. Hertwig dwells on the remarkable up-and-down fitful progress, alternately from one individual to another, by way of the uniting pseudopodia, of masses of plasma, containing granules—a proof of the intimate organic relations of the individuals composing a colony.

The author mentions the success with which, for a time at least, he had been able to preserve examples of this organism in a tolerably natural appearance by the application of osmic acid (1 per cent.); the pseudopodia collapsed only a little, became somewhat varicose, the granules becom-

ing blackish, and the anastomoses remaining—still they lost the resistance of life, floating aimlessly in the water, hanging around the colony like hairs. The application of iodine gave far more unfavorable results.

The author notes that the food captured by this rhizopod is mostly such as is already undergoing decay; rarely do they incept living organisms, but on one occasion he saw a Vorticella captured, and at another some alga-spores. To myself this form appears not to be at all a "hungry" one.

The author's attention was largely directed to the gaining a knowledge of the development of this form. Hertwig first refers to the long-since expressed views founded on the observations of Carter, Wallich, and Greeff, especially of the latter in his *Amœba terricola*, where the so-called nucleus was supposed to be a reproductive organ, which by a breaking up into a number of solid, sharply bounded bodies, and escape of these into the general parenchyma of the body, and in some way combining with certain spermatozoa-like bodies already there, gave rise to so many germs. Carter, on the other hand, formerly supposed that the nucleus gave rise to spermatozoids, whilst the ovula were formed in the surrounding protoplasm; afterwards, as regards *Difflugia pyriformis*, coming more to the views of Greeff, regarding the sexual character of the reproduction as expressed in the "conjugation," a view foreshadowed by Claparède and Lachmann, who regarded the nucleus as a "glande sexuelle."

Bearing these views in mind, the author applied himself especially to a study of the nucleus in this form to see if any evidence should be afforded, demonstrative of its sexual significance; and he believes he has come to the certain result that neither in the formation of new colonies nor in the progress of growth does any process take place other than simple cell-division, in unison with the lowliness of the whole group as simple unicellular organisms.

To arrive however, at any conclusion it was requisite to discover (1) the mode in which new colonies are produced, and (2) the mode of growth of a colony already begun.

In regard to the former question the author, confirming my own record of two nucleated bodies within a single parent test, carries the observation a great deal farther. In a number of individuals of a colony so subdivided into two, he found that one of these portions became changed into a zoospore, which swarmed away from the colony independently. On one occasion he noticed certain individuals containing *two* nuclei, but without having witnessed the act of subdivision into the two daughter individuals.

But it is easy to find examples in which this process is complete, that is, the body of the Microgromia separated into two usually anterior and posterior halves (fig. 8, *a*). Only the former, which is produced into the pseudopodial stem remains in connection with the protoplasmic network of the colony. The posterior segment, which subsequently becomes a zoospore, has now its connection with the mother colony severed, that it is now an independent body. Both together now completely fill the cavity of the test, each having its nucleolated nucleus and contractile vacuole. In this condition the organism may persist for a long time without any perceptible alteration. By-and-by the posterior segment becomes gradually pushed up alongside the anterior one (fig. 8, *b*); amœboid movements ensuing, it slowly makes its exit from the test, as it were guided along by a pseudopodium, the contractile vesicle foremost, the nucleus behind. It maintains for a time its amœboid action, now becoming elongated, now contracted into a globular figure, or here and there lobed (fig. 8, *c*), which play is kept up for about a quarter of an hour; it finally assumes an ovate figure, the end containing the contractile vacuole still in connection with the pseudopodium, the end containing the nucleus outwards. About this time can be noticed a tremulous movement and two flagella which seem fitfully to change place, are seen waving about, but without producing as yet any forward motion (fig. 8, *d*). Their action soon, however, becomes more regular, the zoospore unmoors itself from the pseudopodium of the mother colony and swims away, as an ovate body, with a constantly rotating movement.

The anterior somewhat pointed end now consists of a somewhat homogeneous plasma; it encloses the nucleus and carries the two flagella; the posterior rounded end is richly granuliferous and contains a single or double contractile vacuole. Although the movement of the zoospore is not a rapid one, the author was not ever able to follow it up to its coming to rest; it would always disappear amongst the unavoidable tangle of algæ, &c., taken up in the drop; he therefore could not determine whether it, like the large zoospores of *Clathrulina elegans*, passed directly by retraction of the flagella into a resting state, or whether, like the zoospores emanating from the cysts of that species, they passed through the so-called actinophryan state.

Certain modifications of the mode described might, however, take place. Thus the hinder segment on emergence might assume an actinophryan aspect; the pseudopodia mostly, however, confined to the anterior end; these might sometimes anastomose, and generally resemble those of the

colony; by their slow action the segmented portion became pushed along, dragging after it the pointed hinder vacuole-containing end. The author was able to follow one of these till it came to rest. Becoming ovate, it now developed at the hitherto posterior end a pointed protoplasm-process; inasmuch as this agreed in relative position, as regards nucleus and contractile vacuole, the author was inclined to regard it as the commencement of the pseudopodial stem, but, even after two days' observations of the individual, he could not follow out the formation of the test, manifestly a very slow process.

The substitution of the actinophryan germs for the flagellate zoospores, when, by the light of modern observations, we consider the relation of flagella to pseudopodia, is not in reality very surprising. In the zoospores of Microgromia itself the author had satisfied himself that at first the flagella were temporarily projected and completely retracted only to be reproduced at a new place.

Touching the further question of the growth of the colony, the author was unable to see how from a single individual so originating a second individual becomes developed in connection with it, though doubtless it is by a similar process of self-division. In the course of the author's observations during the summer, he frequently found "Cystophrys" colonies in which in the greater number of the individuals the body was divided into two; the two segments, however, side by side, each with its nucleus and contractile vacuole. In these cases he never had an opportunity to follow the subdivision from beginning to end so as to decide whether the fission took place transversely or longitudinally. From the fact, however, that he noticed so many cases in which the pseudopodial stem was subdivided and the connection of both portions with the colony seemed still maintained, he concluded that the fission was longitudinal. He was, however, able sometimes to see one of these portions slowly make its exit from the test, leaving the other behind; the contractile vacuole in front, the nucleus hindermost. But unlike the zoospores, no amœboid action ensued, the mass remaining globular, near the mouth of the test, and in union with the remaining portion by a broad protoplasmic process (pseudopodial stem); by degrees it assumes the characteristic bilateral symmetry (before described). As regards the formation of the test the author has nothing certain to record.

The author mentions, finally, yet a third modification of this mode of development. In certain colonies, so undergoing subdivision, he noticed several individuals whose test

contained three segments (each with nucleus and contractile vacuole)—one large and two small—their pseudopodial stems in mutual connection; hence they must have arisen by a longitudinal fission of the original body-mass. In several instances the author was able to follow the exit of the two smaller individualised portions, one after the other. For more than an hour the young individuals each crept along a pseudopodium like little Amœbæ, without showing any inclination to become modified into zoospores or to leave the colony. The author was unable to carry this observation any further.

Although an encysted state must doubtless take place during the dry periods of the year, the author did not see any indication of it.

So far as its simple development-history is disclosed by the foregoing observations, there is nowhere any indications of any sexual process. At no point was there any difference in the nucleus observable. The only process observed and described was simple self-division, but the mode of origin of the two nuclei, whether by division or fresh formation, remained to the author in abeyance.

Cienkowski carried out some observations on a form referred by him hereto, and I believe it must be identical with this (although I doubt if Microgromia ever shows the pseudopodia so extremely finely linear and filamentary, and so seemingly homogeneous and granuleless, as he depicts in his figure); he noticed many cases of self-division, mostly longitudinal, but likewise often transverse, and in both cases the one segment emerged from the test as a zoospore, so that he seems rightly to place no value on the circumstance of the fission being longitudinal or transverse. As regards the act of self-division it was always preceded by the appearance of a second nucleus, which he states to *originate independently*, and not by the division of the "mother nucleus;" the plane of subdivision of the body may be oblique or longitudinal. As to the mode of exit, movement and general structure of the zoospore, the author's account agrees with Hertwig's, but he avers that it is a matter of indifference, which segment—the upper pseudopodial-stem-bearing, or the under simply rounded one—may emerge to become the zoospore. He was unable to make out anything definite as to the mode of origin of the colonies, though such seemed to be more abundant in the summer months. (My own opinion is the autumn, often late, is the season in which the Rhizopoda of the freshwaters are most readily to be met with.)

The formation of zoospores thus seems to be bound up with

no particular season; in Microgromia Hertwig found them in spring, Cienkowski late in autumn.

It is quite unnecessary here to dwell on the manifest generic distinctions of this form from the other Monothalamatous monostomatous Rhizopoda—such as Euglypha, Cyphoderia, Trinema, Plagiophrys, Lecythium, Pleurophrys, all again so distinct *inter se*. So distinct indeed *per se* does the rhizopod forming the type of the genus Microgromia appear, that so far as I am concerned I cannot at all recognise this species in the form alluded to, and figured by Schulze[1] and called by this name. The form here in question (*M. socialis*) can by no means be one and the same with "*Difflugia Euchelys*," Ehrenb, or "*Arcella hyalina*," Ehrenb. The most prominent distinctions at first glance are the close application of the body-mass to the test all round, and the long straight but very slightly branched non-granuliferous pseudopodia, and no pulsating vacuole—distinctions which I cannot doubt carry with them essential deep-going specific, even generic, differences. The form no doubt seems to be "social" in habit, but this would be a question of habit merely. It may make a species, possibly a new one, rather of Claparède and Lachmann's genus Plagiophrys.

As regards the genus Gromia, Duj., to which, to say the least, our *Microg. socialis* comes most close, Hertwig bases its generic distinctness on the bilateral symmetry of the test, its firmness and inflexibility; the interspace between the body and the test (though it may at first probably appear but trivial, this is, I fancy, in reality an important character), the single nucleus. All these are specialities of this form, no doubt; but whether they are of generic value as distinguished from the genus Gromia is more, I fancy, a matter of opinion than of any real importance—the rhizopod in question, whether we call it *Gromia socialis* or *Microgromia socialis*, seems to be, *per se*, a very distinct thing. Still I have, on a few occasions, met with even a more minute form, undoubtedly a "Microgromia," but not to be, I think, identified with my original and Hertwig's form. I venture to call it (at least *ad interim*)

Microgromia mucicola, sp. nov. (Pl. VIII, fig. 9).

This I at first found nestling only in the thick mucous matrix of the little alga, which I formerly felt obliged to refer to the genus Dictyosphærium, Näg. (but which is really a Des-

[1] F. E. Schulze, 'Schultze's Archiv für Mikrosk. Anatomie,' Bd. XII, p. 119, t. vi, f. 7—13.

midian of exceptional structure, of which more, it is to be hoped, on a future occasion), under the (provisional) name of *D. constrictum*. This summer, however, I found this rhizopod (in Connemara) for the first time nestling in the mucous investment of the little alga of similar habit, *Cosmocladium Saxonicum*, de Bary. The test is smaller than that of *Microg. socialis*, less pear-shaped, does not appear to offer at least any marked bilateral symmetry, is much more slow in movement and in flow of the granules in the plasma of the pseudopodia. In fact, one has to watch it a long time to notice any alteration, which, however, can be seen by close attention; still I had seen it several times before I thought it was a thing of life at all, so inert is it. I never saw any "Cystophrys" condition, nor even so large groups as even the minor ones of *Microg. socialis*, two only, or at most three, in mutual connection by the pseudopodia. The whitish nucleolated nucleus and very obscure vacuoles are there, as in the other form, whilst occasionally one can see subdivided individuals. Though having so little to communicate on this form beyond the record of its existence, and offering the accompanying effort to convey an idea of its aspect, leaving out of view any attempt to show the thick, sometimes semiopaque and striated,[1] mucus in which it nidulates, I feel quite inclined to believe it will turn out to be in reality specifically distinct.

Plagiophrys sacciformis, Hertwig et Lesser[2] (Pl. VIII, fig. 11).

considerably resembles in figure *Pl. cylindrica*, Clap. et Lachm. Like that species it is irregularly cylindrical, attenuated towards the end, the membranous test irregularly wrinkled and capable of certain slight alterations of figure. As in other forms the body-mass completely fills the test, and

[1] This *striated* appearance of the mucus is due to certain radially but irregularly arranged, if I might so say, *tubular* passages therein, in which lie little more or less elongate Bacilli, or at least short bacillar filaments of "Oscillatoriaceous" nature, when detached by pressure or otherwise, endowed with a spontaneous backwards and forwards *tottering* kind of movement, as mentioned by me in the 'Dublin Microsc. Club Minutes.' Many Desmids and other Algæ besides the two above mentioned are prone to harbour these Bacterian (?) organisms which can sometimes be seen moving up and down inside the tubular passage through the mucus, to and from the body of the alga, and, as has been said, may sometimes ultimately make their way off altogether from beyond the periphery of the mucous envelope. I am not aware whether or not this curious phenomenon has been noticed by other observers.

[2] Loc. cit., p. 114, t. III, f. 3.

consists of a more or less richly granular protoplasm. The authors never noticed any vacuoles, but could readily discern the nucleus, which always appeared, on application of acetic acid, to be homogeneous and a nucleolus could not be perceived.

The pseudopodia are mostly few and homogeneous. In these characters they differ from Claparède's *Pl. cylindrica*, where they are very numerous, and granuliferous. In the present form they are rather quickly projected and withdrawn. The authors give the dimensions as follows: Length, 0·035 mm., breadth at middle, 0·025 mm.; thus considerably smaller than *Plag. cylindrica*.

Plagiophrys scutiformis, Hertwig et Lesser[1] (Pl. VIII, fig. 10),

is distinguished from the preceding by its peculiar shield-shaped figure, owing to its being so strongly compressed; otherwise as to body-structure, pseudopodia, nucleus, this agrees with the preceding. Its dimensions are greater. Length, 0·06 mm., breadth, 0·04 mm.

I must myself quite agree with the authors in holding this in itself as a distinct species from the foregoing and others.

I perceive by a note appended at the end of their work that the authors do not regard the form I recorded as occurring in this country and referred to *Plagiophrys spherica*, Clap. et Lachm., as truly identical therewith, but as probably the same species as their *Pl. sacciformis*, though they quite agree in my interpretation of its general structure. No doubt our form comes very near *Pl. sacciformis*, nor have I, as little as these authors, as yet been able to recognise in our form the presence of any contracted vacuoles. But the action of such may sometimes be so slow and their size so minute, whilst even their existence may be obscured by the density of the surrounding granular plasma, that their presence or absence is often very difficult of determination. Claparède's and Lachmann's figure is so insufficient, and their description so brief and vague, that the absolute determination of what their species actually may be is sufficiently difficult.

I am glad they too agree with my conjecture that the second form[1] which I drew attention to, and have tried to represent on the same plate, is a distinct species. Having already at large adverted to it, I may only here avail myself

[1] Loc. cit., p. 115, t. III, f. 2.
[2] 'Quarterly Journal of Micr. Sci.,' vol. XI, p. 146. [3] 'Proc. Royal Irish Academy,' ser. ii, vol. i.

of sufficient space to name it *Plagiophrys Hertwigianua*, a liberty taken with the name of that distinguished observer of which I hope he may approve; in which case, indeed, I shall feel that I am greatly more honoured than honouring.

An Account *of* Professor Strasburger's Observations *on* Protoplasm. By Sydney H. Vines, B.A., B.Sc., Fellow and Lecturer of Christ's College, Cambridge.[1] (With Plate IX.)

In spite of the numerous researches which have been undertaken of late years in order to gain some knowledge of the properties and intimate structure of that substance which, from its universal occurrence in living organisms, has been termed the "physical basis of life," and to which Hugo von Mohl gave the name "Protoplasm," our information is still quite insufficient to enable us to form any satisfactory hypothesis upon which the so-called vital phenomena exhibited by this substance might be explained. In these "studies" Professor Strasburger gives some account of his observations in this direction.

Pringsheim,[2] in his work upon the vegetable cell, first described the protoplasm as consisting of two layers,—an external hyaline layer in contact with the cell-wall, and an internal granular layer in contact with the cell-sap, though a lamination of the "primordial utricle" had been previously mentioned by Braun, Göppert, Cohn, and von Mohl. In his former work[3] Strasburger has described a similar differentiation as occurring in cells which are entirely filled with protoplasm. Under these circumstances he suggests that instead of Pringsheim's terms "Hautschicht" (cortical layer), and "Körnerschicht" (granular layer), the terms "Hautplasma" and "Körnerplasma" should be used, of which the nearest English equivalents are perhaps "ectoplasm" and "endoplasm."

A differentiation of the same kind has been found to exist in the protoplasm of cells which do not possess a cell wall. Sachs found the zoogonidia of Vaucheria to consist of a central mass of protoplasm, in which the numerous chlorophyll-grains are imbedded, invested by a layer of hyaline proto-

[1] 'Studien ueber Protoplasma,' Jena, 1876.
[2] 'Pflanzenzelle,' p. 4. 1854.
[3] 'Zellbildung und Zelltheilung,' 2 ed. P. 280.

plasm. The plasmodia of Myxomycetes, especially such as move but slowly, were found by de Bary[1] and Hofmeister[2] to show evident differentiation into ecto- and endoplasm. Among the Rhizopoda, the Monothalamia Lobosa have indications of such a differentiation in their pseudopodia, and in the true Amœbæ, the whole protoplasmic mass, is distinctly differentiated into the two layers. The ciliated cells of sponges also show a separation into the two, ecto- and endoplasm, the former of which sends out the cilium and forms a collar round its base, as James Clark, Carter, and especially Haeckel have shown. Max Schultze[3] goes so far as to say that a cortical layer appears to be differentiated in every mass of protoplasm which is functionally a cell, but this is not of universal occurrence, although it is very frequently the case. Prof. Strasburger, in opposition to Max Schultze's view, brings forward some of the Rhizopoda, such as the Heliozoa, which consist wholly of granular protoplasm, that is, of protoplasm which corresponds to the endoplasm of those forms in which differentiation has taken place.

Although these various observers are unanimous in asserting the frequent presence of the hyaline ectoplasm, they do not all regard it as indicating a true differentiation.

Hofmeister,[4] who pointed out, in opposition to Pringsheim, &c., that the ectoplasm is firmer than the endoplasm, attempts to account for its greater density by ascribing to the protoplasm the general property of drops of fluid of being more dense towards their surface than towards their interior. Pfeffer[5] regards this dense hyaline layer, to which he somewhat loosely applies the term "primordial utricle," as a membrane of precipitation. He writes, "Protoplasm brought into contact with pure water, or watery solutions, covers itself, by precipitation, with a delicate membrane, the so-called primordial utricle, and this is the case whether the protoplasm be living or dead." It is evident, however, that the ectoplasm is not so sharply defined from the endoplasm as to warrant the use of the word "membrane" with regard to it, and as a farther objection to Pfeffer's view it may be urged that the ectoplasm, as will subsequently be shown, often possesses a structure which is entirely different from that of the endoplasm. Prof. Strasburger goes on to give an account

[1] 'Mycetozoen,' p. 41. 1864.
[2] 'Pflanzelle,' p. 3, 1867.
[3] 'Protoplasma,' p. 58. 1863.
[4] 'Pflanzenzelle,' p. 3.
[5] 'Sitz. der Niederrheinischen Gesellschaft für Naturwiss. zu Bonn,' 1875.

of experiments which leave no doubt as to the incorrectness of Pfeffer's theory. When the filamentous cells of Vaucheria were cut across, a rounded mass, consisting of endoplasm and cell-sap was, discharged, and he could distinctly see the free borders of the remaining ectoplasm inclining towards each other and finally coalescing, and thus closing up the wound. Many observers[1] regard the ectoplasm as being merely the hyaline substance which is the basis of the protoplasm, but Prof. Strasburger believes that his observations indicate that it is a definite modification of this ground-substance; which is endowed with various properties quite distinct from those of the ground-substance or basis of the endoplasm. He must not, however, be understood to mean that a surface-layer ("Oberflächenhäutchen," "Contact-membran," Max Schultze) is not formed upon the surface of masses of naked protoplasm when exposed to the action of air or of liquids. He only objects to the identification of such a layer, formed in a purely mechanical manner with the ectoplasm, which he regards as the product of a true process of differentiation.

From the foregoing observations we may infer that the simplest form in which protoplasm occurs is that of a uniformly granular mass, and that the first step toward a greater complexity of structure is the differentiation of an external hyaline layer which invests the more fluid internal granular portion. We will now follow Professor Strasburger in his researches into the intimate structure of these two substances.

1. *The ectoplasm.*

In his account of the plasmodia of Myxomycetes, to which allusion has already been made, Hofmeister[2] calls attention to the fact that the ectoplasm presents a radial striation, and occasionally a striation running parallel to the free margin. Sachs[3] finds a similar appearance in the ectoplasm of the zoogonidia of Vaucheria; Tschistiakoff[4] finds it also in the "primordial utricle" of the pollen grains of Conifers, and Strasburger also found it in the ectoplasm of rapidly growing cells when he was investigating the process of division in Spirogyra orthospira. In order to arrive at the true significance of these appearances, he made a series of experiments with a variety of reagents upon the zoogonidia of Vaucheria

[1] Sachs: 'Lehrbuch,' 4th ed., p. 41, 1874.
[2] 'Pflanzenzelle,' p. 24.
[3] 'Lehrbuch,' p. 41.
[4] 'Bot. Zeitung,' 1875, p. 99.

sessilis. Under the action of absolute alcohol the structure of the ectoplasm became very evident, but the cilia suffered; with one per cent. solution of chromic acid the structure of the ectoplasm was not clear, but with one per cent. solution of osmic acid, the structure of the ectoplasm was well brought out and most of the cilia remained uninjured. (Figs. 1, 2, 3).

From these osmic-acid preparations it appears that the ectoplasm contains imbedded within it small rods with relatively large interstices between them, these interstices being filled with watery protoplasm. Externally and internally these rods come into contact with a very delicate continuous layer of protoplasm, the internal layer not being very clearly defined from the endoplasm in which the chlorophyll-grains are imbedded.

It appears, further, that the cilia arise from these denser portions of the ectoplasm, each rod bearing a cilium which is more slender than the rod and about twice as long.

The ectoplasm first appears at the anterior end of the zoogonidium, and is gradually developed towards the posterior end. When it at length invests the whole surface, it is about twice as thick anteriorly as posteriorly. The above mentioned structure can be made out in it at its first appearance.

In order to follow the development of the cilia, Professor Strasburger made a series of observations upon fresh material, and he found that their formation followed closely upon the differentiation of the ectoplasm. In the earliest stage the cilia are small processes of the ectoplasm corresponding in position to the rods at a later stage; they are somewhat longer; the full extremity of each being terminated by a knob; as development proceeds the cilia become longer and the knobs become smaller in proportion to the increase in length, until the final hair-like form is reached. So long as the zoogonidium is in contact with the cellulose wall by which it is surrounded, the cilia are closely appressed to the surface of the ectoplasm, with their apices directed forwards; it is only when the zoogonidium contracts from the cell-wall that the cilia stand out at right angles to its surface and commence their movements. Professor Strasburger points out that this mode of development of cilia resembles the manner in which the pseudopodia of Rhizopods are formed,[1] and he adds that the development of the "bridles" of protoplasm, which occur in the cells of Spirogyra, takes place in the same way. After a longer or a shorter period of activity the cilia are restricted; a knot begins to be formed at the ex-

[1] Max Schultze: 'Protoplasm,' p. 24.

tremity of each, which generally increases in size as the cilium becomes shorter, and which finally coalesces with the ectoplasm.

The hyaline apex of the zoögonidium of Oedogonium, which consists of ectoplasm and which bears a ring of cilia on its posterior margin, give no indications of structure like those found in Vaucheria, nor were any such indications to be found in that part of the zoogonidium of Ulothrix which bears the four cilia. From these facts Professor Strasburger concludes that the above-described structure of the ectoplasm and its relation to the cilia in the zoogonidia of Vaucheria, is a special adaptation, though the occurrence of a radial striation in other places suggests that this special adaptation has been favoured by the molecular structure of ectoplasm in general.

Numerous examples of a striation of the ectoplasm might be drawn from the domain of animal histology. Of these Professor Strasburger avails himself of a few only. He recalls the observation of Ed. van Beneden, that the eggs of star-fishes present a striated outer layer which occupies nearly a third of the radius of the yolk, and he points out the similarity which exists between the "exoplasma" (Haeckel) of many Infusoria with its trichocyst layer, and the ectoplasm of the zoogonidium of Vaucheria with its rods. It must be remembered, however, that all observations tend to show that there is no connection between the trichocysts of Infusoria and their cilia.

It has already been mentioned that the plasmodia of the Myxomycetes are differentiated into an ecto- and an endoplasm, and de Bary, Hofmeister, and Kühne have mentioned the radial striation of the ectoplasm in their accounts of these organisms. Professor Strasburger has been able to confirm their observation, and to add a complete account of the manner in which the pseudopodial processes are thrown out and retracted (Figs. 4 and 5).

The ectoplasm is distinguished from the endoplasm not only by its structure but also by its properties. Close observation of the zoogonidia showed that, after a period of active movement, a cellulose envelope begins to be formed at the surface, and this Professor Strasburger regards as the cause of the cessation of movement. He finds that if such a body be pressed, so as to cause the extrusion of part of its endoplasm, no cellulose envelope is developed around the masses thus set free. If water be added to the zoogonidium, which has thus been deprived of part of its substance, the ectoplasm contracts away from the cell-wall to which it was

applied, and forms, with the remaining endoplasm, a smaller protoplasmic mass lying free within the cellulose envelope. Within a few minutes a fresh cellulose membrane could be detected on the surface of this small mass of protoplasm. On one occasion this process was repeated three times. Hence it appears that the secretion of a cellulose envelope is closely, and even inseparably connected with the presence of an ectoplasmic layer (Fig. 6).

2. *The endoplasm.*

Heitzmann and Frommann have recently pointed out that the substance which forms the basis of the endoplasm often presents a reticulated structure, and Professor Strasburger found the same to be the case in the ovules of Coniferæ and Gnetaceæ, and laid stress upon the distinction to be drawn between vacuoles and chambers in protoplasm. Vacuoles are drops of a watery fluid surrounded by protoplasm, whereas chambers are formed when the cell-sap is traversed by numerous anastomosing plates of protoplasm. Such a series of chambers may be seen in the anterior clear space of the zoogonidia of Vaucheria (Fig. 2).

In many young, and in most mature vegetable cells the endoplasm forms a thinner or thicker layer on the inner side of the ectoplasm. If, under these circumstances, the endoplasm attains a considerable thickness, a distinction can be drawn between its external and internal portions, the former being apparently of greater density than the latter. This is indicated by a difference in the granules imbedded in the one and in the other, and also by the fact that the inner layers are often found to be in motion, whilst the outer are at rest.

Under the influence of the dividing nucleus the hyaline substance forming the basis of the endoplasm of animal cells assumes, during the process of division, a distinctly radial arrangement, the hyaline rays extending for some distance from the two poles of the nucleus. From this it appears that the granules of the endoplasm are repelled from the poles of the nucleus.

During the formation of chlorophyll-grains the endoplasm undergoes a differentiation as well marked as that above described occurring during the process of cell-division. That these structures really belong to the endoplasm is shown by the fact that, in many of the lower algæ, the whole of the endoplasm is coloured green, the ectoplasm alone remaining colourless, and yet they are of greater density than the endoplasm in which they are placed, and they do not present

a granular appearance. They are, in fact, formed from the homogeneous matrix of the endoplasm.

The endoplasm of many Rhizopoda shows a more complete differentiation than any which may be seen in vegetable cells. In the Heliozoa, for instance, the substance of which Professor Strasburger believes to consist of endoplasm only, the distinction of a cortical from a medullary portion, ectosarc from endosarc, is discernible. The nucleus always lies in the endosarc, whereas the ectosarc contains the contractile vesicle.

In Actinosphœrium, for instance, the endosarc is distinguished from the ectosarc in consequence of its coarser granulation. On the other hand, in the Heliozoa Skeletophora, the ectosarc is much more granular than the endosarc, and it subserves the functions of prehension and digestion of food, which, in Actinosphœrium are discharged by the endosarc.

By his observations Professor Strasburger is led to form some general conclusions with reference to protoplasm.

In the first place, he feels himself to be in a position to apply to protoplasm the hypothesis of the molecular constitution of organised bodies which was formulated by Naegeli.[1] In his 'Experimental Physiologie,'[2] Sachs suggests that protoplasm, like other organised structures, may possibly consist of minute solid particles invested by watery areas, and with this view Professor Strasburger entirely concurs. He attributes the definite form and the well-marked vital phenomena of protoplasm to the activity of its molecules, and he refers all those properties which it possesses in common with fluids to the water by which its molecules are invested. The more watery the protoplasm the more evident are its fluid properties, as is shown by the ease with which masses of such protoplasm will coalesce, the rapid protrusion and retraction of processes, &c. The denser the protoplasm, the more exclusively does it exhibit the properties of its molecules. At this point, however, the application of Naegeli's hypothesis to protoplasm must cease. With reference to other organised structures (cell-walls, starch-granules, &c.), Naegeli goes on to show, by evidence drawn from their optical properties, that their molecules possess definite crystalline forms, but there is no ground whatever for believing that the molecules of protoplasm resemble the molecules of other organised structures in this respect.

In the second place he points out that protoplasm is to be

[1] 'Naegeli u. Schwendener des Mikroskop.,' p. 417, ff. 1867.
[2] French edition, p. 469.

regarded as a substance of great complexity of structure, and this view becomes a conviction if the protoplasm of an ovum be considered as the depository of the specific peculiarities of the future organism. Let us take, as an illustration, the Myxomycetes. The plasmodia of the various species of these organisms differ but slightly from one another, when their differences are compared with those existing between the forms of fructification which these plasmodia bear. And yet it cannot be doubted that certain differences, not to be directly detected, but not the less real and active, exist between the plasmodia, and are the agents in the production of such variety in the fructification. We may regard the molecules, the structural units of which protoplasm is composed, as the bearers of these specific peculiarities, and they have recently been recognised as centres of activity by Elsberg[1] and Haeckel,[2] the name of "plastidules" being given to them. That this is really the case is shown by such facts as the following, for instance, that among the Myxomycetes a single plasmodium may bear an unlimited number of fruits, that a portion of a plasmodium is capable of forming a fructification, that a single cell of some higher organisms, such as a leaf-cell of Begonia ,is capable of reproducing the plant, and especially in the reproductive activity of spores and ova. All these facts lead to the conclusion that each of the structures in question contains within itself the special peculiarities of the whole organism of which it is a part. Farther than this we cannot go. We do not know, and we cannot even imagine what mechanism it is by means of which the process of development is worked out, and heredity established. We know only the fact that the course of development is under the influence of heredity. We go on to assume that external conditions lead to the development of new faculties in an organism, which process we include under the expression "adaptation to the environment," but we do not know what is the molecular process by means of which the organism thus responds to an influence acting from without. This we know, however, that the changes, thus produced, if they affect the whole protoplasm of the organism, or at least the protoplasm of the sexual or asexual reproductive cell, are inherited by the succeeding individual.

We cannot assume that all the parts of the organism have their germs in the ovum, for such an assumption would compel us to accept the view that, in the case of those organisms

[1] 'Proc. of the American Assoc.,' Hartford, 1874.

[2] 'Perigenesis der Plastidule,' 1876; see also 'Nature,' No. 350. July, 1876.

of which any single cell is capable of reproducing the whole, each cell contains the germs of all parts of the organism. We should then find ourselves discussing the properties of the protoplasm, not of a single cell, but of the whole organism, in so far as it had not been adapted by some modification of structure to the performance of some special function.

In these remarks, which conclude his pamphlet, Professor Strasburger makes his contribution, from the side of microscopical research, to an explanation of the phenomena of development, its principal point of interest being that the molecules which Professor Strasburger regards as being the structural units of protoplasm, though it must not be forgotten that they themselves are of complex structure, correspond very closely with the "physiological units" postulated by Mr. Herbert Spencer[1] in his account of these phenomena.

Professor E. Van Beneden's Researches *on the* Dicyemidæ.[1] (With Plate X.)

Professor Van Beneden opens his monograph with a short review of the work of his predecessors in this field, amongst whom the chief were Krohn, Erdl, Kölliker, Wagener, P. J. Van Beneden, the father of the present writer, and Ray Lankester. He then tells us that for two months from August, 1874, he devoted his whole time to an accurate investigation of these parasites, working first at Ville Franche and then at Trieste.

The Dicyemidæ have been found as parasites in the following Cephalopoda—*Octopus vulgaris*, *O. macropus*, *Eledone moschata*, *Sepia officinalis*, *S. biserialis*, *Loligo vulgaris*, and *Sepiola Rondeletii*; they were formerly believed by Kölliker to belong to a single species, to which he gave the name of *Dicyema paradoxum*; but this was shown not to be the case both by Wagener and Claparède, and Van Beneden has classified them as follows:—He applies the generic name Dicyema to those forms which are commonly met with in the Octopus, and of these there are two species, *D. typus*,

[1] 'Principles of Biology,' vol. i, p. 183.

[1] Abstract by Mr. D'Arcy Power, Exeter College, Oxford, of a Memoir published in the 'Bulletins of the Royal Academy of Sciences,' of Belgium.

found in *Octopus vulgaris*, and *D. Clausiana*, in *Octopus macropus*. To a second genus, found in the Eledone he gives the name Dicyemella, which is also divided into two species, *D. Wageneri*, from *Eledone moschata*, and *D. Mülleri*, in *Eledone cirrosa*. A third genus, Dicyemina, contains the species *D. Köllikeriana* of the *Sepia officinalis*, and *Dicyemina Schultziana*, from *Sepia biserialis;* whilst a fourth genus Dicyemopsis, contains the form *D. macrocephalus*, inhabiting *Sepiola Rondeletii*.

Modes of preparation.—Prof. Van Beneden finds that the best method of preserving specimens of Dicyema is to immerse the renal organ of the cephalopod in osmic acid 1 per cent. to $\frac{1}{10}$ per cent. for from three to ten minutes, then wash and examine in water or very dilute glycerine (1 in 10); for permanent preparations stronger glycerine is used, and they are stained in a mixture of picrocarmin and glycerine, but to the use of this staining fluid there is an objection, from the fact that it stains the tissues very slowly after the action of osmic acid, weeks or even months being required before a proper tint is obtained. Very dilute solutions of acetic acid (1 in 500 or 800) constitute a very ready dissociator, and bring out the nuclei of the cells very distinctly. Again, the ordinary solution of hæmatoxylin prepared with alum gives good results when it is applied directly to the living organism, for it renders the shapes of both cell and nucleus very distinct, though it ultimately spoils them. Absolute alcohol may also be used; but chromic acid, bichromate of potash and of ammonia, Müller's fluid, picric acid, and saline solution, are worse than useless, for they break up and destroy the cells.

The organization.—The body of Dicyema is composed, first, of an enormous axial cell, which is cylindrical or spindle shaped, and extends from the anterior end of the body to the caudal extremity; secondly, of a single layer of cells forming around the axial cell a kind of simple pavement epithelium. The single axial cell Mr. Van Beneden calls the *endodermic cell*, and he considers it homologous with the endoderm (enteron) of the Metazoa; the layer of cells surrounding this axial cell is similarly the *ectoderm* or *ectodermic layer* (deron) (fig. 3).

Each cell of the ectoderm has an external or superficial face, which is covered with vibratile cilia, an internal or deep face by which these cells are in contact with the axial cell, and lateral faces by which they are joined to each other (fig. 1). Disposed round the anterior extremity of the axis of the body, which may be called the oral pole, are a series

of cubical cervical cells belonging to the ectoderm, which are filled with finely granular protoplasm; their cilia are large and short, and they are regularly placed round the oral pole, whence they are known as polar cells; they are always ranged in two rows of four cells each, which together constitute the polar velum (fig. 2). The heads of *Dicyema Clausiana*, *Dicyemella Wageneri*, and *Dicyemella Mülleri*, are bilaterally symmetrical, and are composed wholly of polar cells. The head of *Dicyemina Köllikeriana* consists of four conical cells placed in a first row, and of five prism-like cells placed between them as a second row, the whole nine of these polar cells forming a very granular opaque body, which veils the anterior extremity of the endodermic cell. There is a second kind of cell found in the Dicyemidæ, to which the name of "parapolar cells" has been given (fig. 2, *p c*), because they are always adherent to the polar cells, and frequently resist even the dissociating action of acetic acid. These cells have a convex internal face, and are nearly elliptical when seen in optical section; they contain finely granular protoplasm, but never any of those refracting globules which are constantly met with in the cells which make up the substance of the ectoderm. In *Dicyemina Köllikeriana* there are two of these cells, and in *Dicyemopsis macrocephalus* four, two ventral and two dorsal; they are in this instance very large, and the external face shows a more or less deep depression, which tends to divide the cell into two parts (see fig. 2). Glancing now at the ectodermic cells which compose the trunk, we find their internal or deep faces are applied to the surface of the endodermic cell, whilst the external, which are always convex, are covered with long vibratile cilia. The number of these cells is probably constant in the same species. In *Dicyema typus* the whole number of cells composing the body is twenty-six in the adult, for there is one endodermic cell, eight polar, two parapolar, and fifteen ordinary ectodermic. Similarly in Dicyemina there are twenty-six cells, of which one is endodermic, nine are polar, two are parapolar, and fourteen are ectodermic. This is readily ascertainable, for the body is broken up under the eyes of the observer by the action of dissociating agents, whilst the parts still retain their relative positions. The form of the cells in embryos and young specimens is often cubical, but with age they elongate in the direction of the main axis of the body, and eventually become fusiform. In well-developed individuals these cells attain a gigantic size. The last two cells together bound a cylindrical cavity, terminated in a cul-de-sac, into which

the endodermic cell is prolonged. There is probably no cell-wall, for the cells are often traversed by embryos which are leaving the maternal body, and they readily take in foreign substances. The cells of the ectoderm, in the immense majority of cases, contain during their development a number of granules and globules, which vary in form, size, and refractive power.

The refractive globules are of two kinds, one perfectly homogeneous and of a spherical or ovoid shape, varying from a size which is scarcely perceptible under the highest power of the microscope, to small masses of 0·03—0·05 mm. in diameter. The other kind are small irregular clots of a granular material. Both descriptions are insoluble in ether and alcohol, are stained first brown and then black by osmic acid, are not coloured either by carmine or hæmatoxylin, and give off no gas when treated with acids. Certain "clear droplets" have been noticed in *Dicyemopsis macrocephalus*, and more rarely in other forms, which are spherical with feeble outlines, and are formed of a homogeneous material which is probably liquid or semi-liquid, and has a gelatinous appearance. They seem to be due to vacuoles in the protoplasm of the cells. There is still a third element, known as the "refracting rods," which helps to fill the ectodermic cells. These bodies are cylindrical, fusiform, or prismatic, and are scattered through the substance of the protoplasm, or are grouped in a transparent droplet, just as crystals of stearine are grouped in a drop of fat. These rods may, perhaps, be the deformed heads of spermatozoa belonging to the host.

The refractive globules are congregated in great numbers in certain cells, so that the surface becomes convex; here and there true warts (fig. 3, *w*) are formed, which are most abundant in *Dicyema typus*. In Dicyemina there is a tendency for the refractive globules to accumulate in the two caudal cells; their nature or function is not known, but that they play no important part in the animal economy is evident from the fact that they vary considerably both in numbers and characteristics in different individuals, and may even be entirely absent.

Each cell of the ectoderm has a flattened oval nucleus, generally situated at its posterior end. When the cell has a wart, such wart is formed by the raising of the central part of the cell (fig. 3), the nucleus being separated from the wart by a membrane with a double contour line, which may be ruptured by strong pressure exerted on the nucleus, which is broken, and the contents, consisting of a semi-liquid, clear

toplasm of the axial cell is finely granular, and there is an oval nucleus with well-defined outline. About this time, when the embryo has elongated into a cylindrical or nematoid body (fig. 9), a germ appears in the central cell on each side of the nucleus; these germs are produced endogenously and have a homogeneous nucleus. The end of the body at which the blastopore was situated now rapidly developes the cells, which ultimately form the polar velum; the cells of the head are differentiated from those of the trunk; the differentiation of the parapolar and caudal cells takes place at a later period, generally after birth. At a given instant the whole body clothes itself with vibratile cilia, the development of which Prof. Van Beneden has not been able to trace, at the same time the embryo elongates and becomes more and more thread-like; vacuoles appear in the protoplasm of the axial cell and the number of germs increases. The embryo at the time of birth is composed of the same number of cells as are present in the adult, and the post-embryonic development consists entirely in the progressive increase of the constituent cells of the embryo.

II. *The Rhombogenous Dicyemidæ.*—These individuals, which produce infusoriform embryos, are shorter and larger than the preceding group; the axial cell, too, is larger, and terminates in front in a rounded end, so that the polar cells are flatter and the head has a different shape to that in the Dicyemidæ producing worm-like embryos. The germs are about double the size of those producing vermiform young, and are not formed directly in the protoplasm of the axial cell, but in a peculiar set of cells, which are themselves produced in the cell of the endoderm; these latter cells, whose formation has not yet been followed, are called the "germ-producing cells," or shortly, the "germ producers" (figs. 4 and 5). They are always few in number, varying from two to four or five, and have an oval nucleus, which is in marked contrast to the spherical nucleus of the germs; the substance of the cells are finely granular. Each germ producer gives birth to several generations of daughter-cells, which are the germs of the infusorian embryos, and are arranged concentrically round the mother-cell (fig. 5). These germs are formed endogenously, and the nucleus of the germ-producing cell takes no part in the formation of the daughter-cells; three or more spherical nuclei appear simultaneously, round each of which a differentiated layer of protoplasm can be distinguished, which is less granular than the protoplasm of the primitive germ producer. Occasionally a radiating appearance may be seen in the

protoplasm of the germs. When the germs have attained a certain size the protoplasm which separates them contracts and collects round the nucleus of the germ producer, so that the germs themselves are driven to the exterior, though they remain attached to the mother-cell till they have attained their full development. A second, third, and even more generations are in like manner formed and driven out, and thus concentric layers of germs are produced, which are larger as they are further from the centre (fig. 5).

The infusoriform embryo at the time when it leaves the mother's body to swim freely in the liquid which bathes the corpus spongiosum of the cuttle-fish is pear shaped, and swims with its larger end, which is known as the head, forwards, whilst the tail, which is conical, is directed backwards. The whole organism is bilaterally symmetrical. The cephalic dilatation is composed of three organs, one of which is symmetrical and is placed in the middle line, the urn ; the other two are unsymmetrical and lateral, one being placed slightly above and the other slightly below the median organ ; these are known as the refractive and the ciliated bodies (fig. 18).

The urn (figs. 18 and 19) consists of a margin which is called the capsule of the urn, of a cover which takes part in the formation of the ventral wall of the embryo, and of a contents. The contents of the urn (*i*) is a cellular body, composed of four segments arranged crosswise, each segment being granular, whence the name of the "granular body" which has been applied to them. The function of the urn is not known.

The refractive bodies (fig. 16 and 18, *r*) are generally two in number, and are not composed of calcium carbonate, as Kölliker and Wagener assert. Hæmatoxylin prepared with alum causes, them to burst in about three quartersof an hour with an explosion which scatters the refracting globules of which they are composed and projects them to some distance; it is then seen that the bodies were encased in a double wall, one within the other, the inner called the endocyst and the outer the ectocyst (fig. 19, *ce*, *ci*). The ciliary body is composed of a number of vibratile cells, each of which is conical and contains a spherical nucleus and a sieve-like plate which gives insertion to a number of very long vibratile cilia (fig. 19, *c*). The germs of the infusoriform embryos, as was stated above, are produced endogenously, in a cell round which they remain grouped until they have reached maturity. Soon afterwards they undergo the first changes previous to the formation of infusoriform embryos. As development progresses they separate from the germ producer, so that, as a general rule,

a series of young in varying stages of development are found on each side of the germ producer, which are more advanced as they are further from the place in which the germs were produced. Side by side with the germs which have arrived at maturity spherical or elliptical bodies with a well-marked longitudinal or transverse striation are often found (figs. 10-14); they are grouped either in fours or pairs, and are only found near germ producers. These striated bodies, as they are called, were at first taken for spermatophores, but this idea was given up, partly after considering the analogous multiplication of vegetable cells, partly in consequence of the investigations of Bütschli on the multiplication of cells. Prof. Van Beneden has come to the conclusion that this characteristic striation is due to modifications which the nucleus undergoes at the moment of cell division. Immediately before division the germ becomes very granular and opaque, and the nucleus increases considerably in size and its nucleolus disappears; a very clear striation then makes its appearance on the periphery of the nucleus, all the striæ meeting at the two poles and running along the meridian of the sphere. A refractive corpuscle then appears at each pole of the nucleus (fig. 10), and very fine granulations collect round each of them. The two poles are then differentiated into a granular polar disc, in which the meridional striæ lose themselves (fig. 11). The polar discs then thicken and become more distinct, whilst the striæ are not so well marked. Very rarely striated nuclei have been seen in which the fibrillæ were a little thicker near the equator than in the rest of their length. The germ has by this time become ellipsoidal, as well as the nucleus, and the polar discs are, so to speak, condensed into two small disc-shaped, refractive bodies, the *derived* pronuclei (fig. 13). Round each of these a clear substance collects from which striæ have sometimes been seen to radiate; these are the *engendered* pronuclei (fig. 13 and 14). Midway between the two derived pronuclei is a granular well-defined plate which is rather thicker towards the centre; this is the Zellplatte of Strasburger. This forms the plane of fission by which the original cell-plate divides into two, and then each derived pronucleus enlarges and becomes more clearly defined; each pronucleus now increases in size, whilst at the same time it changes its position, and from being placed excentrically it comes to be in the centre of the daughter-cell; inside it a small nucleolus is visible. The last traces of the clear striated part of the old nucleus then disappears, and the division is complete. The same series of changes is undergone by the daughter-cells, which eventually give rise to a wall-like

body. Then the embryo appears as a spherical body, composed of a fixed number of cells, amongst which four are remarkable for their unusual shape (fig. 16). The two largest cells form eventually the parietal cells of the urn, and give rise to the capsule, the two middle produce the cover, two cells opposite them the refractory bodies, and finally, at a later period, four small cells appear which become the granular body (fig. 17, 18, *i*). The other cells of the embryo become ciliated and give birth to the ciliated body. The infusoriform embryo then passes into the external medium after traversing the wall of the endodermic cell and the ectoderm; its mode of life and development after this are not known, but it is a remarkable fact that although the adult Dicyema and the vermiform young are killed by immersion in sea water, still the infusoriform embryo swims uninjured for two, three, and even five days in the same liquid. Apparently, therefore, the Cephalopoda must be infected by the infusoriform embryo alone. It has not yet been determined whether it is the embryo itself or the ciliated contents of the urn which becomes the Dicyema—whether the embryo passes directly into a new Cephalopod or whether there is an intermediate host, and whether or not the infusoriform organism is modified in the sea before it enters the body of its host. There are some other points in relation to the Dicyemidæ of which we are yet in ignorance; thus, we do not know what constitutes the difference between a Nematogenous and a Rhombogenous worm whether an individual, after having produced vermiform young, can in advancing age so modify itself as to bear infusoriform embryos; if reproduction takes places entirely by parthenogenesis, or if the production of embryos of either one kind or the other is preceded by true impregnation. It is just possible that before the infusoriform embryos are produced an ectodermic cell may fuse with the central cell of a vermiform embryo, and if this cell is the male element the fecundation of the endodermic cell is of the same kind as the fecundation of the embryo-sac of phanerogams by the pollen tube, the only difference being that the Dicyemidæ would be truly hermaphrodite.

The chief results of the investigation of the Dicyemidæ.

I.—The Dicyemidæ are multicellular organisms formed entirely of cells connected together like the cells of epithelium or of vegetable tissue. They have no muscle or nerve-fibres, and in place of internal cavities they have intracellular vacuoles.

II.—All the Dicyemidæ are composed of an axial or endo-

dermic cell, which is fusiform or cylindrical, and which extends the whole length of the body; and of a layer of cell-plates lying on the surface of this cell, like simple pavement epithelium. There never exists any trace of an intermediate cell-layer, or of a general space between the axial cell and the ectoderm.

III.—The cells which form the anterior extremity of the body form also the head of Dicyemidæ, and they are peculiar in their form and composition. There are eight or nine of these polar cells, and they form the polar velum, being disposed in two rows concentrically round a central point called the oral pole of the Dicyema. Cells called the parapolar may also contribute to form the cephalic dilatation. The Dicyemidæ are bilaterally symmetrical, and this symmetry is particularly well marked in the head of all species and in the infusoriform embryos.

IV.—The ectoderm is made up of cell-plates which form half canals, and are applied by their concave faces to the axial cell. In these cells refracting globules appear, which accumulate at certain points to form protuberances, to which Prof. Van Beneden has applied the term "warts."

V.—The endodermic cell has the structure of a vegetable cell, or the endodermic cells of a Hydromedusa or the body of a Noctiluca. It is traversed by a protoplasmic network, whose meshes are filled with a hyaline fluid of gelatinous consistency.

VI.—It is in this cell of the endoderm that the germs are formed, and it is here that they develope the embryos.

VII.—Each species of the Dicyemidæ includes two kinds of individuals, the Nematogenous and the Rhombogenous, which differ in their external characteristics, in their organization, and in the character of the germs which they produce, in the mode of formation of these germs, and in the development and constitution of the embryos. The Nematogenous produce vermiform embryos, and the Rhombogenous infusoriform embryos.

VIII.—The Nematogenous germs are produced endo-
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of the cells which compose it, for after its birth it does not form a single new cell. The number of cells in the body is twenty-six in the Nematogenous individuals of *Dicyema typus* and *Dicyemina Köllikeriana*. A Dicyema is a permanent gastrula person, whose endoderm is composed of a single cell.

The germs of Rhombogenous Dicyemidæ form endogenously in special cells situated in the axial cell. These creative cells have been called germ producers or germigens, and only a small number of them exist in the axial cell. Each germ producer forms a number of successive generations of germs, which are characterised by their size, by their granular appearance, and by the dimensions of their nucleus. After true cleavage has occurred a small sphere is formed at the expense of each germ; these spheres, which ultimately become the infusoriform embryos, are composed of a certain number of cells, some of which are large whilst the rest are small. The infusoriform embryo consists of three parts—an urn, a ciliary body, and two refractive bodies which are united to form a single organ. The embryo so constituted is bilaterally symmetrical. The urn, placed at the side of the belly, consists of a cap, of a cover, and of a contents; it is composed of four granular bodies, each of which encloses several cell-nuclei, and they become ciliated when they have attained their full development. The two refractive bodies are produced in two neighbouring cells, they partially cover the urn in front and form the main part of the dorsal face of the embryo. The ciliary body composes the caudal part of the pyriform embryo, and is formed of a fixed number of ciliated cells. The vermiform embryo developes in the Cephalopod in which it is born, whilst the infusoriform embryo probably distributes the species by transmitting the parasite from one cephalopod to another.

Relationships of the Dicyemidæ.—The Dicyemidæ are separated from the Protozoa, even to a casual observer by the fact that they are multicellular; but they have no third cell-layer, so that they can scarcely be admitted into the group of the Metazoa without some essential modification of the definition which is ordinarily given of this group. Hitherto the Dicyemidæ have for various reasons been classed as Vermes by such writers as Kölliker, Von Siebold, G. Wagener, and Ray Lankester; but even in this heterogeneous group there is no type which offers any analogy to the parasites of which we are treating. The organization, too, of the Dicyemidæ is much simpler than that of any of the known Metazoa, for they are composed of a very small number

of closely united cells, which live together and form a secondary aggregate. No differentiated organ or internal cavity is present, so that they are distinctly of a lower grade of organization than the Metazoa, while the fact of their being multicellular raises them above all the Protozoa. They are best placed, therefore, in an intermediate position, under a new group, the "Mesozoa," which may be characterised as multicellular organisms, composed of two kinds of cells, one layer of which is external or peripheral, performs all the functions of animal life, and is a true ectoderm; whilst the second layer, being the internal or central, performs the vegetable functions and constitutes the endoderm. No vestige of a third cell-layer is present, nor is there any connective tissue, cœlom, vessels, muscular fibres, or nerves.

If the development of the Dicyemidæ be taken into consideration, we should also be inclined to place them under the group of the Mesozoa, for the gastrula is epibolic, the endoderm is represented by a single cell, and the completely developed organism is only this gastrula enlarged, with the blastopore closed, and, as before stated, the gastrula of the Dicyemidæ is comparable with the gastrula of osseous fish.

All organisms which form the transitional stages between the Protozoa and the Metazoa must be classed under this new group of Mesozoa. Before the appearance of the first Metazoa, a certain number of cellular persons produced from a single individual, instead of dividing, continued to live together to form the first multicellular organism. The Magosphæra of Haeckel gives us some idea of what might have been the appearance of these multicellular organisms; the protoplasm was then differentiated either by invagination or delamination into ectosarc and endosarc. If the differentiation had taken place by delamination the resulting organisms would, like Magosphæra, have consisted of a single row of identical cells, arranged in a vesicle or in a sphere, and characterised by a homaxial symmetry; if the differentiation had taken place by invagination, the symmetry would have been axial, and the cells would have been differentiated at the two poles. The first mode of differentiation is seen during the development of the Geryonidæ, whilst the second mode occurs in the large majority of the Metazoa.

The number of cells invaginated is very variable; if there are many, the gastrula developes by invagination properly so called; whilst if there are only a few, an epibolic gastrula is formed.

Under the Mesozoa the hypothetical Gastræadæ must be grouped, understanding by the term Gastræa organisms pos-

sessing two kinds of cells, one forming the ectoderm and the other the endoderm, the endoderm being produced by *invagination*. The Planuladæ are hypothetical Mesozoa, which ought to be formed at the expense of a multicellular sphere resembling Magosphæra, in which the two cell-layers are developed by *delamination*. The Dicyemidæ will then be placed amongst the Gastræadœ as actual living types of organisms with only two cell-layers.

On the CHANGES PRODUCED *in the* LUNGS *by the* EMBRYOS *of* OLLULANUS TRICUSPIS. By WM. STIRLING, D.Sc., M.D., Demonstrator of Practical Physiology in the University of Edinburgh. (With Plate XI.)

SEVERAL years ago Prof. Leuckart described a small nematode worm belonging to the family of the Strongylidæ, the *Ollulanus tricuspis*, which affects the cat. The adult forms, male and female, are found in the stomach and intestinal tract even as far as the rectum.[1] They, like the intestinal trichinæ, sometimes occur in such numbers as to give rise to redness and ecchymosis of the mucous membrane of the stomach. This worm is viviparous, and the young embryos, like those of the trichina, migrate within their feline host and become lodged in various organs, where they themselves undergo and give rise to certain changes in the organs wherein they become encapsuled. There are seldom more than three embryos within each female, but the females themselves often occur in great numbers. My attention has been specially directed to the changes produced in the lungs by the presence of these embryos of Ollulanus.

I have had an opportunity of examining the lungs in two cats so affected. Both cats were thin and emaciated and were subject to frequent fits of vomiting. I only preserved the lungs, so that I am unable to state the condition of any of the other organs. Dr. Cobbold[2] has found them in the lungs and liver, Leuckart also indicates the pleura and diaphragm as situations where they may be found. Dr. Cobbold remarks that he has seen tens of thousands of them occupying the lungs, the infested animal perishing by the inflammatory action set up by their presence. Their

[1] 'Die Menschlichen Parasiten.' R. Leuckhart. Bd. ii, p. 102.
[2] 'The Internal Parasites of our Domestic Animals,' p. 125.

presence gives rise to a characteristic and pronounced lesion of the lungs. Just as the word "trichinised" has been applied to an animal infested with trichina, so we may apply the word "*ollulanised*" to an animal infested with ollulanus, and we may, following the case of trichina, call the disease *ollulaniasis*.

On removing the lungs from the body they were found to be studded with small rounded bodies about the size of a pin's head, and quite visible to the naked eye. On making a section of the lung it is found that these small millet-seed-like bodies are distributed generally throughout the lung texture, under the pleura, and in the vesicular structure of these organs. They stand out as little white specks, especially well in a lung whose blood-vessels have been filled with a blue gelatine mass.

Mode of preparing the lung for microscopic examination.—Before removing the lungs from the body, the trachea was opened and the bronchi and air-vesicles were filled with a quarter per-cent. solution of chromic acid. The trachea was then ligatured and the distended lungs were then placed in a large quantity of a similar solution for three to four weeks and then cut up into small pieces and hardened in spirit. Sections were then made and examined in various ways.

Of course, in the case of the lungs it is impossible to use a mixture of paraffine as the embedding medium, for it runs into and blocks up the air-vesicles. It is especially for such vesicular organs that the freezing microtome is so valuable. In order to freeze the lung the spirit must first be removed by soaking it in water. Before embedding the lung in gum in the freezing microtome, it will be found an improvement to soak the piece of lung itself in a thick syrupy solution of gum, a solution strongly recommended by Ranvier, and which will be found very useful for many other organs, and especially for those that are friable. As, however, one sometimes desires to make sections with the razor in the hand, another method is required. For this purpose the lung, after being soaked for twenty-four hours in gum, is then hardened for a similar period in rectified spirit, and the hardening completed by immersion for a few hours in absolute alcohol. The spirit coagulates and hardens the gum and renders the tissue quite hard and compact, so that it can be easily cut with a knife. The sections are then placed in water, which dissolves the gum and leaves them ready to be mounted either unstained or after staining in any of the ordinary ways. For a lung hardened in chromic acid logwood will be found very useful. It may be used in the

ordinary way, or the plan which is advantageous in some cases may be followed, viz. to over-stain the sections in logwood until they become quite dark; by allowing a drop of strong glacial acetic acid or dilute hydrochloric acid to act on the stained section for a minute or so, much of the superfluous pigment is removed and the section may then be mounted in glycerine or Farrant's solution in the ordinary way.

It so often occurs that glycerine after a time renders unstained sections so transparent that they are of very little value. This difficulty is best got over by placing the sections of the lung hardened in chromic acid in a quarter per-cent. solution of perosmic acid for forty-eight hours. The perosmic acid exerts its "fixing" properties still quite well, and especially renders the connective tissue of a yellow colour, causing it to be easily recognised and the elastic tissue and outlines of nuclei and cells to become far more sharply defined. Even the white substance of Schwann in a nerve of such a section of lung so hardened will be blackened by it after hardening in perosmic acid. This reagent is very strongly recommended for the above purposes.

The existence of fat normally in the lung.

The well-known property of perosmic acid, viz. to blacken fat-cells, enables one at once to detect the presence of such structures. In the last edition of 'Quain's Anatomy'[1] it is stated that fat does not occur in the lungs. It most certainly occurs amongst the tissue surrounding and accompanying the bronchi, lying immediately outside the cartilages; indeed, it occurs in such quantity as to be very easily recognised even without the agency of perosmic acid.

If we examine a thin section of such a lung hardened in chromic acid, say with a power of fifty diameters, we find that it presents the appearance seen in Pl. XI, fig. 1. It represents the appearance seen immediately underneath the pleura. The pleura itself, *a*, is greatly thickened, and this is due to an increase in the connective tissue, resulting from pleuritis, in all probability set up by the presence of these parasites. The nodules, *b*, for the most part somewhat rounded in shape, represent the mass of reticulated tissue that exists around the worms. The details in structure are not filled in, as this figure is meant only to give a general view of the relation of the various parts. The spaces *c*, here left empty in order not to confuse the drawing, represent the *empty* capsules in which the coiled-up worms are lodged. Generally more than one worm coiled up exists within its reticulated mass,

[1] 'General Anatomy,' p. 60.

and it is easy to see how the vesicular texture of the lung is encroached upon by these nodules. The letter *d* points to a transverse section of an artery, and shows the immense thickening of the middle coat, which will be alluded to later.

Although several worms may exist within each nodule, each individual worm has around it a special capsule, and there is never more than one worm within a capsule. It lies, as it were, coiled up within a little cyst of its own, and several of these cysts are held together by the reticular tissue around them. The cyst itself consists of connective tissue. It is generally round in shape, and the coiled-up embryo either occupies it entirely or there is a narrow space left between it and the wall of the cyst, which is filled with a clear fluid. Leuckart[1] remarks that the lungs are studded with a greater or less number of small cysts, which enclose one or more embryos. The wall of the capsule, he continues, is of such a considerable thickness that it not unfrequently exceeds in diameter two or three times that of the space in which each worm lies. Now, it seems to me that there is a distinct thickened layer of connective tissue round each worm, and the other reticular tissue around each embryo or group of embryos must be regarded as the result of an interstitial inflammation, and thus it is that several worms come apparently to be enclosed within each nodule. These nodules are not of any definite size or shape, though generally somewhat rounded, but they are often of quite irregular outline.

These nodules at first sight give the lung the appearance of one affected with miliary tuberculosis, for which one is at first very apt to mistake them.

If we examine a similar section taken from immediately under the pleura, but in an earlier stage, when no pleurisy exists, we find that these nodules always give rise to little elevations immediately underneath the pleura, presenting exactly the same appearances as Burdon-Sanderson has described in the case of tuberculosis.

Fig. 2 shows two nodules taken from the substance of the lung, and examined with obj. iv, oc. 3, Hartnack, *b* represents a cyst with a worm coiled up within it, and *a* shows a degenerated worm. The reticular structure of the nodule is well brought out, and the outer layers present that compressed appearance not unfrequently observed in true tubercle. The epithelium around the margins of the mass is often found to be proliferating. This figure also shows how these nodules by their growth gradually encroach on the lumen of the air

[1] Loc. cit., p. 103.

vesicles (*d*). The two masses *a* and *b* were originally distinct, but they have gradually increased in size until they have joined and formed practically one irregular mass. In the air-vesicles around these nodules there is often to be found a large number of catarrhal cells.

If now we take one of the nodules seen in fig. 1 (*b*) and examine it under obj. viii, oc. 3, Hartnack, we find it presents the appearances seen in fig. 3. Here we have four capsules represented, one (*a*) empty, two (*b*, *b*) others contain a finely granular mass slightly shrunk from the wall of the capsule and representing the degenerated worm, and another (*c*) gives the appearance of the worm as it exists coiled up within its capsule. This shows that all the worms within any individual mass do not reach the same stage of development at the same time. The tissue surrounding and holding all these capsules together is shown to be made up of a branching and an anastomosing (*d*) network, giving rise to a reticulated appearance, such as is seen in a lymphatic gland, with here and there small masses (*d*) which appear like nucleated branched cells whose branches anastomose with the adjacent fibres of the reticulum. Within the meshwork are a number of nuclei which appear as if they were free. These nuclei are specially well brought out by the action of logwood. In some of the nodules this reticulated tissue becomes much compressed near the circumference of the nodule, as shown in fig. 2.

In many nodules also there is often a considerable amount of pigmentation, such as so frequently occurs in other diseases of the lungs.

Not unfrequently are to be met with amongst this reticulum multinucleated masses of protoplasm which may be termed giant cells, as seen in fig. 4, (*a*). They are granular in appearance, contain a great number of nuclei, and give off a series of processes which anastomose with the fibres of the meshwork in which they lie. With regard to these giant cells I propose to direct attention at another time.

The outer portion of these nodules, where they project into the air-vesicles, are covered by epithelium, which is in some places proliferating, and the air vesicles adjoining present all the appearances of catarrhal pneumonia. Many of the catarrhal cells in those sections steeped in perosmic acid are seen to be partially filled by granules blackened by this reagent. These contained granules seem therefore to be of a fatty nature.

The distribution of these embryos in the lungs is entirely confined to the vesicular structure, for if a section of the

lung is made so as to contain a transverse section of a bronchus we never find any of these embryos in the connective tissue or in the lymphatic tissue which so abundantly accompanies the bronchi. It is easy to find these small nodules in the vesicular structure passing quite up to the connective tissue surrounding the bronchi, but never in it. This connective tissue in the larger bronchi is open in its texture, lying chiefly outside the cartilages, and is accurately mapped off from the adjacent vesicular structure, and in a transverse section of such ollulanised lung many leucocytes are to be found within its meshes.

Now, how do these embryos reach the lungs, and how can we explain the changes they produce there? Leuckart maintains that they migrate from the intestine as embryos and pass into those organs in which they become lodged. They are thus said to migrate within their host, after the manner of the embryos of trichina. The trichina embryos, however, follow specially the course of the connective tissue, but it is an interesting and important point that in the case of ollulanus none of the embryos are to be found in the connective tissue around the bronchi. Leuckart did not succeed in finding any embryos in the blood.

It seems to me that the embryos ultimately find their way and become lodged between the air-vesicles, and that they, by their presence, give rise to an interstitial inflammation, resulting in the formation of the numberless nodules already described. These nodules occur in tens of thousands. As the inflammatory action proceeds the nodules gradually increase in size, encroach upon and obliterate neighbouring air-vesicles, rendering great areas in the lung apparently solid. Each embryo becomes surrounded by a special capsule of condensed connective tissue. Leuckhart found no embryos in the blood in his cases.

Changes which the embryo undergoes within its capsule.—It is at first coiled up within its capsule, but after a time it loses its mobility and its body degenerates, so that many of the capsules appear to be filled with an oval mass of fine granules. In fact, this mass of granules resembles an ovum undergoing segmentation, and Meissner was led into error by regarding it as an ovum, viz. that of *Ascaris mystax*, though he left unanswered the quesiton how it got there. I have no doubt also that the ova described by Henle[1] as occurring in the cat's lung were simply these degenerated forms of ollulanus.

The degeneration which the worm itself undergoes is of a

[1] 'Allgemeine Pathologie,' II, p. 789.

fatty nature. This is beautifully brought out by perosmic acid. The fully formed encapsuled worm is not blackened, but wherever an embryo is beginning to undergo this change, the perosmic acid blackens the fatty particles, and when the degeneration is complete the capsule appears as if it were filled with a black oval mass.

With regard to the fully formed embryo, probably the most notable point about it is, that when it is uncoiled it is of comparatively immense proportions, measuring 0·32 mm. in length, whilst the adult female form measures only 1 mm.

Local changes in the blood-vessels.

Apart from the direct local changes produced by the presence of these parasites, these local changes give rise to other important changes in the blood-vessels of the lungs. By the existence of such a large number of inflammatory lesions, little tubercles, (one may call them) are formed, and encroach upon and obliterate a great number of vascular capillaries and thus destroy a great vascular area, rendering small but excessively numerous foci impervious to the blood. What is the result? The same amount of blood has to be propelled through the lungs, but now, owing to the presence of these small nodules causing obliteration of many capillaries, the resistance to the passage of the blood through the lungs is increased, and the heart, in order to overcome this resistance, must hypertrophy, and the blood-vessels, especially the pulmonary artery, in order to withstand this extra strain or pressure put upon it by the now thickened heart, must either dilate under the tension or become thickened and so strengthened in order to resist this strain. So we find that the pulmonary artery and its branches throughout the lungs has its middle coat greatly thickened. We have here in the case of the lungs the same condition which is found in other organs, *e.g.*, the kidneys undergoing interstitial inflammation, as in a certain form of Brights' disease, leading to thickening of the middle coat of the arteries. Similar conditions obtain in the case of aortic obstruction, which leads to dilatation of the left ventricle and thickening of its walls.

Fig. 1, *d*, shows a transverse section of the pulmonary artery so thickened, and the lumen has also become diminished. The same is shown in fig. 5, which represents an artery opened into somewhat obliquely, and gives a transverse and longitudinal section of the vessel with its immensely thickened middle coat and its diminished calibre. The thickening of the middle coat was extremely well marked in all the arteries of the lungs.

A CONTRIBUTION *to the* ANATOMY *and* PHYSIOLOGY *of the* RETINA. By Professor FRANZ BÖLL, in Rome. (Translated from a paper communicated to the Royal Academy of Science in Berlin, November 12, 1876; published in 'Monatsbericht der K. Akademie der Wissensch. zu Berlin,' November 23rd, 1876.)

THE numerous histologists who, in continuation of the well-known researches of Max Schultze, have lately examined and described the rods and cones of the retina, which are considered to be the terminal organs of the optic nerve, have always believed that they had these interesting structures before them in an "absolutely fresh" or "still-living" state. But there can be no doubt that, up to the present time, not one of all these observers has investigated a single retina of any vertebrated animal in a true physiologically fresh condition, for they have all, without exception, missed the very remarkable properties of the truly living retina, which will be now described for the first time.

If a frog which has been kept in the dark be decapitated (the lower jaw is best left attached to the trunk), if an eyeball be then dissected out with the least possible loss of time, cut in half with scissors, and the retina detached with fine forceps from the dark ground of the retinal pigment and the choroid, it appears at the first moment of an *intense purple-red colour,* so that one might think a blood-clot had been taken up by the forceps. During the next ten or, in favorable cases, twenty seconds (stage 1), this colour gradually fades, and after this time has usually disappeared altogether. The retina then shows, during the next thirty to sixty seconds, sometimes even longer (stage 2) a satiny lustre. Gradually this also becomes lost, and the retina becomes perfectly transparent, in which state it remains for a quarter of an hour or more (stage 3). Then it gradually becomes turbid and opaque (stage 4).

Concerning the causes of these hitherto unknown optical properties of the physiologically fresh retina, microscopic examination shows that both the purple colour of the first stage and the satiny lustre of the second are seated exclusively in the layer of rods, or rather in their strongly refracting external segments, which are composed of extremely delicate superimposed plates; these appear purple-red in the first stage, and shine like satin in the second. Towards the end of the second stage the rods swell up and

gradually lose their lustre, as they lost their purple colour at the end of the first stage. Their refractive index approaches that of the other layers of the retina, which now, in the third stage, becomes quite transparent. The opacity of the retina in the fourth stage is due, not to changes in the layer of rods, but to coagulations of albuminous substances which take place in the other layers.

These peculiarities of the living retina are found in all animals which possess a fairly developed layer of rods. Among vertebrata, in addition to amphibia, I could find them in cartilaginous and teleostean fishes (of which I examined a great number of species and individuals at Viareggio this autumn) and in mammals. I must here mention that the purple colour of the first stage is generally longer and better preserved in cold-blooded animals and in those which have the largest rods (amphibia and cartilaginous fishes) than in warm-blooded animals and kinds with very delicate rods (teleostean fishes and most mammals), in which the retina often passes with extraordinary rapidity from the purple tint to the second stage.

In the two remaining vertebrate classes, birds and reptiles, the study of the living retina is surrounded by peculiar difficulties, as we know it already shows a brilliant and permanent coloration, caused by the presence of variegated fat-drops. This coloration naturally renders it extremely difficult to determine any change of tint in the first stage. But in the pigeon I have succeeded in showing an undoubted and distinct paling of the central red part of the retina in the first ten seconds, so that I must conclude that the intense red colour of the pigeon's retina must be due, not only to the red fat-drops, but also to an optical change occurring in the external segments of the rods; the characteristic satin-like lustre of the second stage is also always very distinct in the retina of birds. On the other hand, in the retina of the lizard (the only reptile which I have hitherto examined) I have found no indication of the appearances which characterise the first and second stages; I will not decide whether they were obscured by the intensely yellow colour of the retina, which is due to fat-drops, or whether the extremely rudimentary development of the outer segment of the rods in this retina may be insufficient to give rise to the optical phenomena described.

The same characteristic purple colour may be also shown in the eye of invertebrate animals. Already in 1842 Krohn stated that the large rods of the retina of cephalopoda had a purple-red colour in the fresh state. The same is known

to be the case with the rods of heteropoda, and former observers have already called attention to the red colour of the optic rods in crustacea, lepidoptera and coleoptera. I had the opportunity at Viareggio of examining numerous species of cephalopoda and massive crustacea in the fresh state, and found in all, without exception (in the cephalopoda in the layer of rods, in the crustacea in the optic rods, which are composed of five plates), exactly the same purple colour which I had discovered in the retina of vertebrata. In these invertebrata it is much more intense, and is preserved much longer and better than in vertebrata.

It seems, therefore, to be a general rule that the peculiar substance composed of superimposed layers of plates, which in the retina of vertebrata forms the external segments of the rods and cones, and in the eye of invertebrata physiologically (perhaps also phylogenetically) equivalent organs (the rods of cephalopoda, and the optic rods of arthropoda), shows a very characteristic purple-red colour in all these animals, which is very intense during life, and mostly fades with extreme rapidity after death.

This purple colour appears to be completely identical in the eyes of all animals that have been hitherto examined. My friend and colleague M. Blaserna, who observed the colour of the retina of a frog with a small spectroscope while I was preparing it, immediately determined its entire difference from the colour of hæmoglobin, and further decided that it does not correspond to any simple spectral colour, but must be considered compound. A confirmation of the correctness of this view may be derived from microscopic examination. For sometimes the colour of the first stage is continued long enough to enable one to decide in a microscopcal preparation of the frog's retina that in the mosaic of the layer of rods, when focussed by the microscope, all the optical transverse sections of the rods do not appear red, but that among a very large majority of red circles a minority (about ten per cent. on a superficial reckoning) appear of a greenish-blue tint.

Concerning the nature of these colours of the external segments of the rods, I hope soon to give further explanations in a subsequent communication, and especially to be able to decide the question whether they depend on a special colour of the plates themselves or whether they are due to the optical properties of the plates, these being themselves colourless. In the latter case they would be classified among the phenomena of interference.

In this subsequent communication I will further develop more completely certain physiological corollaries, which

result from anatomical discovery above mentioned, and which may be now at least shortly referred to:

1. The red colour of the back of the eye as seen by the ophthalmoscope does not depend upon illumination of the blood-vessels of the choroid, but arises essentially from the purple colour peculiar to the retina.

2. This special colour of the retina is only present during life, and survives the death of the animal (especially in warm-blooded animals) only a few seconds. If a dying animal be examined with the ophthalmoscope (it is best to kill it with chloroform) the moment of death is marked by a sudden paling of the red fundus oculi; on this fact an easily applicable method of determining death may be without difficulty founded for forensic purposes.

3. The special colour of the retina is considerably diminished *intra vitam* by incident light. Diffused daylight makes the purple colour of the retina pale. Long action of direct sunlight (dazzling) completely decolorises the retina. In the dark the intense purple colour is immediately restored.[1]

This objective alteration of the outer segments of the rods by rays of light undoubtedly forms a part of the act of vision.

We append here a communication by Professor Arthur Gamgee to 'Nature,' February 1st, 1877, on Professor Kühne's recent observations induced by Böll's discovery.

Professor Kühne read before the Naturhistorisch-Medicinischer Verein of Heidelberg, on January 5th, 1877, a paper entitled 'Zur Photo-chemie der Netzhaut,' in which, while confirming the fundamental statement of Böll, he has recorded a number of new facts of great interest.

Kuhne's Researches on Photo-chemical Processes in the Retina.

On January 5th, Dr. W. Kühne, Professor of Physiology in the University of Heidelberg, read before the Naturhistorisch-Medicinisches Verein, of Heidelberg, a paper entitled "Zur Photo-chemie der Netzhaut," so full of interest to the

[1] These facts were not yet known to me when, in June of the present year, I demonstrated the red retina of the frog at Berlin to MM. du Bois-Reymond, Helmholtz and Pringsheim. The frogs used for the purpose had been kept in a rather light room, and my demonstration only succeeded after about half a dozen frogs had been sacrificed in vain. If care has been taken to keep the frogs in the dark, the demonstration, with a little skill, succeeds without fail in the first eye.

physicist and physiologist, that I think an abstract of it will be acceptable to the readers of 'Nature.'

A short time since, Böll (a pupil of Max Schultz and Du Bois-Reymond, who now occupies the chair of physiology in Rome) communicated to the Berlin Academy the remarkable fact that the external layer of the retina, *i. e.* the layer of rods and cones, possesses in all living animals a purple colour. During life, according to Böll, the peculiar colour of the retina is perpetually being destroyed by the light which penetrates the eye; darkness, however, restores the colour, which vanishes for ever almost immediately after death.[1]

The wonderfully suggestive nature of Böll's discovery led Kühne to repeat his observations; in doing so, whilst he has confirmed the fundamental statement of Böll, he has ascertained a number of new facts of great interest.

Kühne's observations were made on the retinæ of frogs and rabbits. In the first place, implicitly relying upon the statements of Boll, he examined, as soon as possible after death, the retinæ of animals which had been kept for some time in darkness. He soon found that the beautiful purple colour persists after death if the retina be not exposed to light; that the bleeching takes place so slowly in gaslight, that by its aid the retina can be prepared and the changes in its tint deliberately watched; that when illuminated with monochromatic sodium light the purple colour does not disappear in from twenty-four to twenty-eight hours, even though decomposition have set in.

The first observations of Kühne on the vision-purple (*Sehpurpur*), as he terms it, whilst they showed that the disappearance of the colour is not, as Böll has asserted, a necessary concomitant of death, removed many of the difficulties which stood in the way of a careful investigation. Carrying out his preparations in a dark chamber illuminated by a sodium flame, Kühne was able to discover the conditions necessary to the destruction of the vision-purple as well as some facts relating to its restoration or renewal.

As long as the purple retina is kept in the dark or is illuminated only by yellow rays, it may be dried upon a glass plate without the tint changing; the colour is not destroyed by strong solution of ammonia, by saturated solution of common salt, or by maceration in glycerine for twenty-four hours.

[1] This account of Böll's researches is taken from Kühne's paper. The latest number of the 'Monatsberichte' of the Berlin Academy which has yet reached Manchester, which includes the Proceedings for September and November, does not contain Böll's communication, which is of later date (November 12).

On the other hand, a temperature of 100° C. destroys the colour, and alcohol, glacial acetic acid, and strong solution of sodium hydrate produce the same effect.

Kühne's next observations were directed to the discovery of the influence of light of different colour upon the vision-purple. It would appear that the more refrangible rays of the spectrum have the greatest action, and that the red rays are as inactive as the yellow.

Kühne now found the incorrectness of Böll's assertion that the retina of the living eye exposed to ordinary daylight does not exhibit the vision-purple, for on preparing the eyes of animals which had just been exposed to light, as rapidly as possible in the chamber illuminated by sodium light, he discovered that the retina was of a beautiful purple. It was only when eyes were exposed for a considerable time to the direct action of the sun's rays that a fading of the purple colour was perceived.

A most suggestive experiment now threw some light upon the circumstances which retard the decolorisation, and which restore the vision-purple. The two recently extirpated eyes of a frog were taken; from one the retina was removed, whilst an equatorial section was made through the other eye, so as to expose the retina and still leave it *in sitú*. Both preparations were exposed to diffuse daylight, until the isolated retina had lost its purple colour. On now taking the other preparation into the yellow chamber and removing the retina, it was found that its colour yet remained: it was *dark red*, but was bleached when exposed in its naked condition to daylight.

This experiment was confirmed by others, in which the effect of strong sunlight was substituted for that of diffuse daylight.

But the most curious results of Professor Kühne's experiments have reference to the restoration of the vision-purple. If an equatorial section be made through a recently extirpated eye, and a flap of retina be lifted up from the underlying choroid and exposed to light, the purple colour of the flap will be destroyed, whilst the colour of the rest of the retina persists. If, however, the bleached portion of the flap be carefully replaced, so that it is again in contact with the inner surface of the choroid, complete restoration of the vision-purple occurs. This restoration is a function of the *living* choroid, probably of the living retinal epithelium (*i. e.* of the hexagonal pigment-cells, which used formerly to be described as a *part* of the choroid), and it appears to be independent of the black pigment which the retinal epithelium

normally contains. As it is absolutely dependent upon the life of the structures which overlie the layer of rods and cones, it is natural that it should be observed to occur for a longer time after somatic death in the frog than in the rabbit.

Kühne's researches, though suggested by the interesting observation of Böll, have not only corrected many errors which that observer had committed, but have led to the discovery of facts which add immensely to the importance of the newly observed vision-purple.

They have shown that the living retina contains a substance which under the influence of light undergoes chemical changes, which vary in intensity according to the intensity and character of the luminous rays, and they point to the existence of structures in connection with the retina which as long as they are alive are able to provide fresh stores of substance sensitive to light.[1]

Since the above account of Kühne's researches was written, he has published in the 'Centralblatt der Medicinischen Wissenschaften' (January, 1877, No. 3) a short paper, dated January 15th, in which he announces the startling confirmation to his previous researches afforded by his *having been able to obtain actual images on the retina which corresponded with objects which had been looked at during life* (!)

The discoveries of Böll and Kühne must, as the latter remarks, have led to the thought that after all there might be some truth in the stories which we all have heard of images seen in death being left imprinted upon the eye. After his first researches Kühne endeavoured over and over again to observe on the retina of rabbits bleached spots corresponding to the images of external objects, but his endeavours failed. As Kühne remarks, and as all readers who have understood his experiments will allow, in order to obtain a permanent photograph, or, as he terms it, *optogramme*, the effect of the light would have to be so prolonged or so intense as to destroy the balance between the destruction of the vision-purple and the power of the retinal epithelium to restore it.

Kühne took a coloured rabbit and fixed its head and one of its eyeballs at a distance of a metre and a half from an opening thirty centimètres square, in a window-shutter. The

[1] I have repeated all the more important observations of Kühne with the eyes of several *Ranæ temporariæ*, and with those of two rabbits, of which one was an albino, and can entirely confirm all his interesting facts. In ordinary daylight, the purple-red colour of the frog's retina, and its subsequent decolorisation, may be most satisfactorily demonstrated. The use of the dark chamber illuminated by sodium is, however, useful in cases where the dissection of the eye has to be conducted with care.—A. G.

head was covered for five minutes by a black cloth and then exposed for three minutes to a somewhat clouded midday sky. The head was then instantly decapitated, the eyeball which had been exposed was rapidly extirpated by the aid of yellow light, then opened, and instantly plunged in 5 per cent. solution of alum. Two minutes after death the second eyeball, without removal from the head, was subjected to exactly the same processes as the first, viz. to a similar exposure to the same object, then extirpation, &c.

On the following morning the milk-white and now toughened retinæ of both eyes were carefully isolated, separated from the optic nerve, and turned; *they then exhibited on a beautiful rose-red ground a nearly square sharp image with sharply defined edges; the image in the first eye was somewhat roseate in hue and less sharply defined than that in the second, which was perfectly white. The size of the images was somewhat greater than one square millimètre.*

Professor Bunsen was amongst the witnesses of this beautiful experiment.

ARTHUR GAMGEE.

In a last communication to the 'Centralblatt,' No. 4, 27th January, 1877, Professor Kühne describes a very simple method of optography, which from its singularity may be used even for demonstration purposes. It is this. The head of an ordinary rabbit kept in the dark after having been severed is placed for ten minutes in such a position that one eye is turned upwards, *i.e.* directed against one of the large skylights of the laboratory, then the head is turned so that the other eye may be exposed to the same influence. The time of exposition was so long on account of the clouded condition of the sky. After leaving them for twenty-four hours in 5 per-cent. solution of alum, both eyes showed the most marvellous images on the posterior surface at the retina; one recognises with great distinctness the outlines of the skylight and the boards which were placed above the glass as beautiful red stripes, and at some distance from them there were seen even the top lights, the image of which could not have been expected. The microscopic examination showed complete integrity of the external segments of the rods in the white parts of the images.

On Some Points *in the* Early Development *of the* Hen's Egg. By P. Kidd, B.A. (With Plate XII.)

The object of this paper is twofold:

(*a*) To describe a peculiarly irregular form of segmentation observed in several eggs.

(*b*) To discuss the relations of the germ and the large formative cells lying on the floor of the subgerminal cavity, to the finely granular material forming the floor of that cavity in the first hours of incubation.

(*a*) The only observations on irregular segmentation that I can find are those relating to—

(i) The appearances of unfertilised eggs when freshly laid, or when taken from the oviduct.

(ii) The changes occurring in such eggs after incubation.

A full account of such observations is given by Oellacher, 'Zeitsch. für Wissensch. Zoologie,' Bd. 22 ("Die Veränderungen des unbefruchteten Keimes des Hühnereies im Eileiter und bei Bebrütungsversuchen").

Oellacher quotes the earlier researches of Dumas and Prevost., 'Zeitsch. für Organ. Physik.,' 1828, and states that his results agree more or less with theirs. Oellacher finds that unfertilised hens' eggs freshly laid or taken from the oviduct present appearances comparable to those occurring early in the development of fertilised eggs. The blastoderm, in these cases, undergoes segmentation to a greater or less extent, but the further stages in the development of the fertilised ovum are wanting. On incubating such eggs for eight hours, the cells of the upper layer of the germ were seen to be smaller than usual at this stage of incubation, especially at the centre; whereas the peripheral cells were much larger and less numerous.

After incubation for two or three days the central portion of the germ undergoes a retrograde metamorphosis, and is gradually replaced by a finely granular mass. The cells at the periphery at the same time become smaller and more numerous, and they all finally undergo a similar granular change.

On the fifth day of incubation solution of the germ and yolk took place. Oellacher's investigations were not carried further, as there seemed to be no object in doing so.

Bischoff ('Ann. des Sciences Nat.,' iii sér., Zool., t. ii) found segmentation in the unfertilised ova of the frog and the sow, and Leukart (art. Zeugung, 'Wagner's Handwb.

der Phys.,' 1853, Bd. iv) also describes segmentation in the unfertilised ova of frogs.

Hensen (' Centralblatt,' 1869, No. 26) noticed segmentation in the unfertilised ova of rabbits.

Waldeyer, "Die Epithelialen Eierstocksgeschwülste," 'Archiv für Gynækologie,' 1870, ii Heft, suggested that the dermoid cysts of the ovary may have a parthenogenetic origin from the ova therein.

I now proceed to describe the irregular segmentation that I have observed myself. In seven eggs that were incubated for different periods, varying from eight to fourteen hours, it was noticed that segmentation had apparently recently begun or had proceeded very slowly. In all these cases segmentation was not nearly as far advanced as in normal unincubated eggs. The finely granular blastoderm in sections of some of these eggs appeared to be divided up into a comparatively small number of large irregular masses, some of which appeared about to divide into smaller masses. In other cases the blastoderm was seen to be divided into two parts, separated from each other by an interval as in figs. 1 and 2. In these latter cases segmentation was more advanced than in the preceding cases. In each instance the blastoderm rested on a finely granular bed or layer, which separated the blastoderm from the white yolk. In places this finely granular layer was sharply defined towards the germ, in other places it seemed to pass insensibly into it. But in all cases this layer gradually shaded off more or less into the subjacent white yolk. This finely granular or "subgerminal layer," as we shall call it, sometimes formed a continuous floor beneath the blastoderm from one end to the other; at other times it was massed in wedge-shaped blocks at one or either end of the blastoderm, and was continued as a fine strip towards the centre beneath the blastoderm. These wedge-shaped peripheral thickenings of the subgerminal layer were very clearly marked in some cases, as will be seen on referring to the figures 3, 4, 5, and 6.

In a few sections where these peripheral thickenings were most marked the subgerminal layer was seen to be more sharply defined at these points towards the subjacent yolk, a fine cleft separating them in certain cases. The lateral extension of the subgerminal layer over the white yolk at the periphery of the blastoderm varied considerably in extent, and here as throughout its extent this finely granular layer was more or less beset with vacuoles.

In a few instances these vacuoles contained a large cell-like mass exactly resembling the segmentation masses of

the germ. Oellacher describes a similar appearance in a freshly laid unfertilised egg.

No subgerminal cavity was visible in any of these irregular blastoderms.

All these eggs were prepared by hardening in very dilute chromic acid, and finally in weak alcohol, or by treatment first of all with osmic acid, and subsequent hardening as before in chromic acid, and finally weak alcohol.

Staining with carmine, aniline colours, hæmatoxylin, and chloride of gold was tried, but unstained osmic-acid preparations were the most satisfactory.

Six of these seven eggs were procured at one place, and the seventh at a different place, so that they must have come from at least two different hens. I know nothing about the hen that laid the last egg, but the hens that laid the other six were kept with a cock, so that it is very probable that all these six eggs were fertilised.

There are two possible explanations of this irregular segmentation. Either the eggs were all unfertilised or they were fertilised, but segmentation proceeded very irregularly and slowly. The first supposition is improbable for the reason already given; and on comparing Oellacher's drawings of segmented blastoderms of freshly laid eggs, in the paper already quoted, with these irregular blastoderms which I incubated for eight to fourteen hours, I find that Oellacher's blastoderms show more advanced segmentation as a rule than mine, although I incubated them as long as fourteen hours. This would suggest that the conditions in the two sets of cases were not identical, and I am inclined to think that this difference consists in the fact that the blastoderms in my cases were fertilised but that for some reason segmentation had become arrested and had proceeded irregularly.

The irregular segmentation might, perhaps, be partly accounted for by the fact that the eggs were laid in November, development being generally less regular in winter than in summer.

If it had been known that these eggs possessed this peculiarity before they were examined microscopically, they might have been examined before incubation and after prolonged incubation. Such a course could not have failed to throw light on the investigations. But, as it was, these eggs were met with quite unexpectedly, and their nature was only made out after hardening.

However, in face of the facts which have been mentioned already, I think we may conclude that some, if not all, of these eggs were fertilised.

The eggs alluded to offered such a favorable opportunity for the study of the relation of the germ to the subgerminal finely granular layer, that we shall discuss this relation in connection with these eggs first before referring to normal eggs.

The point that we are endeavouring to prove in this part of the present paper is that the finely granular subgerminal layer is richly nucleated, and gives rise to nucleated masses which are separated from this layer previous to the formation of the subgerminal cavity, and become fused with the germ (as in fig. 6); later on they constitute the well-known "formative cells" or "Dotterzellen" (Goette), which are seen on the floor of the segmentation cavity after the appearance of that cavity.

Before describing in detail our own observations on these relations, we shall mention shortly the results obtained by previous observers on these points. His was the first to suggest that the embryo is not exclusively developed out of the blastoderm proper, and asserted that the white yolk took a prominent part in the development of certain tissues of the embryo, particularly the blood. He described the blastoderm proper as the archiblast or "Hauptdotter," and the white yolk as parablast or "Nebendotter." Though it is generally admitted that the conclusions of His were inaccurate, inasmuch as nearly all subsequent observers deny that the white yolk participates in segmentation, yet these observations probably directed the attention of later workers on the hen's egg to the existence of a very finely granular layer, "the subgerminal layer," forming the superficial surface of the white yolk beneath the blastoderm. At any rate, the importance of this layer has been shown to be very great in the eggs of Fishes by Bambeke, Klein, and Balfour, as will be mentioned presently.

Waldeyer was unable to decide whether the large formative cells or masses lying on the floor of the subgerminal cavity arose from the white yolk or not, but agreed with His in so far as he contrasted the products of segmentation of the blastoderm with the eventual products of white yolk. Waldeyer distinguished a "Hauptdotter" and a "Nebendotter" like His, and described the products of segmentation of the former only (viz. blastoderm) as primary descendants of the ovum.

Peremeschko ('Stricker's Histology,' vol. iii, p. 527, Eng. edition) states that the large granular cells in the floor of the subgerminal cavity increase considerably in number in the first hours of incubation. And since, he urges, this

of the "couche intermédiare" closely resembles that of the germ; it is nucleated and finely granular like the germ, but as a rule the granules are rather coarser here than in the germ. The nuclei resemble those of the germ. He does not regard the nuclei of the "couche intermédiare" as derived from the nucleus which appears in the germ on fertilisation, *i.e.* after disappearance of the germinal vesicle, but distinguishes them from the nuclei of the germ cells proper.

Klein, in the April number of this Journal, 1876, has described the changes occurring in the subgerminal layer, or "Parablast," as he calls it, in the early development of the ova of Trout. He describes the "parablast" (which he distinguishes from the "archiblast" or blastoderma) as existing in the earlier stages in the form of a peripheral wedge-shaped mass like van Bambeke's "bourrelet," and provided with a large number of nuclei of a rather peculiar character. The nuclei resembled those of the germ in being vesicular and pale, and in many cases were deeply notched or divided into lobes; round nuclei were not often seen. Klein draws a sharp distinction between the "parablast" or subgerminal layer, and the white yolk, and gives several reasons for not regarding the former as white yolk. He describes the large formative cells as arising from the parablast, and gives several drawings representing large nucleated masses arising from the finely granular nucleated "parablast."

Balfour ('Journ. Anat. Phys.,' April, 1876) in one part of his communication on the development of Elasmobranch Fishes, describes nuclei in the upper part of the yolk beneath the segmentation cavity, and found that the nucleated yolk undergoes cleavage. Balfour regards the "couche intermédiaire," "parablast," or subgerminal layer as yolk, and speaks of the "nuclei of the yolk."

We shall now describe more particularly the appearances in our own cases. In all the seven blastoderms which we have previously referred to, the blastoderm rested on a finely granular bed, the subgerminal layer or "parablast" (Klein). The extent of this layer varied in different specimens. The characters of this layer were very definite. Under low powers it had an extremely finely granular appearance, and looked as if it had been dusted over lightly with a fine powder. It resembled the blastoderm in appearance very closely; but, as was noticed by van Bambeke in Teleostean Fishes, the granules of the subgerminal layer were slightly coarser than those of the germ. Where the sections were

thin enough, and especially in osmic-acid preparations, nuclei could be distinguished more or less throughout the whole layer. In those cases where the peripheral thickenings of this layer were well marked, these thickenings were seen to possess numerous nuclei. The nuclei were never quite as easily seen in the subgerminal layer as in the blastoderm itself, as the former was more coarsely granulated.

The nuclei were often arranged in clusters as if rapid division were going on at this point, especially at the peripheral thickenings. The irregularity of the segmentation of these blastoderms precluded the possibility of determining whether this subgerminal layer was in the first instance deposited, as Bambeke and Klein believe is the case in Teleostean Fishes, as peripheral thickenings which subsequently grew inwards and met beneath the blastoderm, or whether this layer was a portion of the germ left behind when the blastoderm was raised from the white yolk by the appearance of the segmentation cavity. In the latter case the subgerminal cavity would be more correctly described as "intra-germinal." However, from the general appearance the former view seems more probable.

In some cases (as in fig. 6) the subgerminal layer seemed absolutely continuous with a large mass forming part of the blastoderm. This mass was nucleated almost throughout, and its appearance was identical with that of the subgerminal layer. In other cases smaller segments seemed as if they were about to become separated from the subgerminal layer, and in many cases it was absolutely impossible to define the limits of germ and subgerminal layer, one passing imperceptibly into the other.

As we have remarked in the first part of this paper, in some cases the vacuoles which appear so constantly in this layer of which we are speaking were occupied by large nucleated masses which seemed to lie free in the vacuole. In other cases a vacuole might be seen to open on the floor of the segmentation cavity, and a large cell-like mass was seen lying half in the vacuole and half in the segmentation cavity. The appearance of these blastoderms resembled very closely those described and figured by Klein in the ova of Trout, so much so that in many cases it would be impossible to distinguish them.

It is clear that these observations resemble Goette's to a certain extent; but we believe that there are some very important differences between us. In the first place, Goette regards the subgerminal layer as yolk. The fact that the subgerminal layer gradually shades off into the

white yolk may seem to favour the view that no distinction can be drawn between the two. But the structure of this layer so closely resembles that of the germ, as we have already more than once insisted, that we should on this ground alone be justified in drawing a distinction between the white yolk and the finely granular subgerminal layer which Kölliker does not hesitate to denominate protoplasmic. But the fact that nuclei are found throughout this layer in all the specimens of which drawings are given, is a still stronger proof that in this structure we have to deal with germinal matter. If any further proof were needed we might cite the case which is represented in fig. 6 to show the unity of the germ and the subgerminal layer. When the blastoderm is seen to be directly continuous, as in this case, with the subgerminal layer, it is hard to imagine what other explanation can be given than that these two different parts are fundamentally of an entirely similar nature.

It is true that Goette does state that nuclei were visible in some of the projections of the floor of the subgerminal cavity, but he does not state whether nuclei were found throughout the extent of the floor of this cavity, and in his drawings certainly does not represent such an arrangement of nuclei as I have described.

To return to the nature of the subgerminal layer. The finely granular aspect which is so well marked immediately beneath the segmentation cavity gradually changes to a more coarsely granular appearance as it nears the white yolk, and finally is replaced entirely by white yolk. But does it follow because small yolk-granules are found in this layer in increasing numbers towards the white yolk that therefore this finely granular material is itself white yolk? We think not. What is more likely than that protoplasm in contact with the food granules of the yolk should take up these granules for its own nutrition? Taking all these facts into consideration, and especially relying on the presence of nuclei in large numbers in this layer, we think ourselves justified in regarding the subgerminal layer as essentially of a germinal character. On this view the great importance of this layer will be at once apparent from the part that the formative cells are believed to take in the development of the embryo. A study of the anatomical relations of the germ and subgerminal layer in these irregular blastoderms suggested that similar relations might obtain in the case of normal blastoderms.

Examination of normal eggs, unincubated and incubated for periods as long as sixteen or eighteen hours showed that

this was the case. A drawing is given in fig. 7 of the floor of the segmentation cavity in an unincubated but normal egg, showing nuclei distributed more or less throughout this layer. In some blastoderms incubated as long as sixteen or eighteen hours, the subgerminal layer was very much reduced in size, and in some cases no longer formed a continuous layer, the white yolk projecting between the segments of the subgerminal layer and assisting to form the floor of the segmentation cavity. Nuclei could be detected in these detached portions of the subgerminal layer in some cases. This would seem to show that the subgerminal layer continues to play an important part in development for some time after incubation has commenced. I am not able to state accurately how long the subgerminal layer persists and can be recognised after incubation has commenced.

These investigations were conducted under the direction of Dr. Klein.

On the PROTRUSION *of* PROTOPLASMIC FILAMENTS *from the* GLANDULAR HAIRS *of the* COMMON TEASEL (*Dipsacus sylvestris*). By FRANCIS DARWIN, M.B. (Abstract of a paper read before the Royal Society on February 28th.)

THE protoplasmic structures described in the following communication are connected with the glandular hairs or trichomes found on both surfaces of the leaf of the common teasel, *Dipsacus sylvestris*. The trichomes are of two kinds, differing in a marked manner and shape. The form of gland from which alone the protoplasmic filaments issue is shown in the diagram. The gland consists of a multicellular pear-shaped head, supported on a cylindrical unicellular stalk which rests on a projecting epidermic cell. The whole structure projects about $\frac{1}{10}$ of a millimeter ($\frac{1}{250}$ inch) above the surface of the leaf.

The filaments issue from inside the gland-cells, reaching the surrounding medium by passing through the external cell-wall of the gland. The point where protrusion takes place is on the summit of the gland, and usually at the point of junction of several radiating cells on the summit of its dome-like surface. The act of protrusion is rapidly effected; a previously naked gland may be seen to send forth a minute thread of trembling protoplasm, projecting from its summit freely into the surrounding water. The filament grows by

clearly visible increments, and may ultimately attain the length of nearly one millimeter. The filaments appear to pass through the substance of the external cell-wall of the glands, as no apertures to allow of their passage have been observed.

Under normal circumstances the filament presents the appearance of a delicate and elongated thread slightly clubbed at its free end, and animated by the perpetual tremble of Brownian movement. The distal end of the filament is often attached to the gland, thus forming a loop. Extremely delicate filaments of great length are often seen entangled in elaborate and complex knots, or several filaments may be seen issuing from a single gland.

The substance of which the filaments are composed is gelatinous, transparent, highly refracting, and devoid of granules. It is stained by tincture of alkanet, and not blackened by osmic acid, and coloured yellow by iodine. These reactions, when combined with results of various physiological tests, show that the filaments contain resinous matter in some way suspended in protoplasm.

The most remarkable point in the behaviour of the filaments is their power of violently contracting. Contraction usually begins at a number of nearly equidistant points, situated close together near the free end of the filament. The curious beading thus produced spreads rapidly down the filament, which ultimately runs violently together into a ball seated on the top of the gland. In other cases contraction takes place without any previous appearance of beading.

Filaments frequently break loose but retain their vitality, and are still capable of contraction although separated from their parent glands; and this observation is of importance, as proving that the movements of the filaments are not governed by forces residing within the glands, but that the filaments are composed of an essentially contractile substance.

The contraction of the filaments is produced by the following causes:

Dilute acids (from 1 to $\frac{1}{5}$ per cent.):—Sulphuric, hydrochloric, acetic, citric, and osmic acids.

Dilute alkaline solutions ($\frac{1}{4}$ to $\frac{1}{2}$ per cent.):—Carbonates of ammonia, sodium, potassium.

Solutions of gold-chloride $\frac{1}{4}$ per cent., silver nitrate $\frac{1}{4}$ per cent., sulphate of quinine $\frac{1}{10}$ per cent., citrate of strychnia (about) $\frac{3}{4}$ per cent., camphor $\frac{1}{10}$ per cent., the poison of the cobra (about) $\frac{1}{4}$ per cent., iodine $\frac{1}{4}$ per cent.

Glycerine.

Methylated spirits.

Vapour of chloroform.

Heat.—The temperatures at which the filaments contract are rather variable, but are all below 57° C.

Electricity.—The induced current causes contraction.

Mechanical stimulation.—The filaments contract when pressure is made on the cover-glass.

The evidence derived from the experiments, whose results are here briefly summarised, appears to be strongly in favour of the view that the filaments contain living protoplasm, and that the sudden movement above described is a true act of contraction. For if the latter hypothesis is rejected, the only remaining view appears to be that the filaments are so constituted as to be capable of undergoing coagulation, by which contractility is mechanically stimulated. But it seems inconceivable that reagents of widely different natures, such as dilute solutions of acetic acid, of camphor, and of gold-chloride, should produce identical chemical effects. Osmic acid is well known to kill protoplasmic structures without making them contact. This characteristic reaction holds good with the filaments of the teasel when treated with sufficiently powerful solutions of osmic acid (*e. g.* 1 per cent.). When killed in an extended position, they cannot be made to contract with strong acetic acid. This observation is of importance in another way; for it proves that the violent movements caused by dilute acetic acids are of a "vital," and not of a simple chemical nature. Moreover, the general character of the reagents and other causes (such as heat, &c.) by which contraction is produced is quite consistent with the belief that the filaments are protoplasmic in nature.

An important series of phenomena are produced by the following fluids:—dilute solutions ($\frac{1}{8}$ or $\frac{1}{4}$ per cent.) of carbonates of ammonia, potassium, and sodium, and infusion of raw meat. If a filament under observation is treated with a drop of $\frac{1}{4}$ per cent. solution of carbonate of ammonia, the following changes occur. The filament contracts, but almost instantly recovers itself, and is once more protruded. The filament, however, does not regain its original form or general appearance; instead of consisting of thin elongated threads of a highly refracting substance, it is converted into balloon-like or sausage-shaped masses of very transparent, lowly refracting matter. These transparent masses are remarkable for the spontaneous changes of form and other quasi-amœboid movements which occur among them.

Dilute infusions of meat cause a similar effect, astonishing quantities of transparent matter being produced.

It has been shown that the filaments are protoplasmic bodies, containing a large quantity of resinous matter. The question next arises, with what processes in plant-physiology is the protrusion of filaments homologous?

The leaf-glands of the teasel are similar in general structure to many glandular hairs which produce resinous and slimy secretions; and, like these glands, they contain bright drops of secreted resin, lying in the centres of the gland-cells; they also resemble many glandular hairs, in being often capped with accumulations of secreted matter. Now, these accumulations stain red with alkanet, yellow with iodine, and are largely soluble in alcohol—that is to say, they consist of substances which have the same reactions as the filaments. There is, in fact, no doubt that the caps of resinous matter on the teasel-glands are produced by the accumulation of dead filaments. According to this view, the act of protrusion is essentially a process of secretion; the resin issues from the gland-cells, mingled with a certain amount of true protoplasm; and it is only from the death of the living or protoplasmic part of the filaments that the resinous accumulation results. This view of the act of protrusion corresponds with the theory of secretion held by some physiologists, viz. that secreted matter is produced by the dissolution or death of protoplasm. That, for instance, the oil in a fat-cell is the result of the disintegration of a plastid or individualised mass of protoplasm, formed in the cell by endogenous cell-formation.

The protrusion of protoplasmic filaments from the glands of the teasel appears to bear an obscure relationship to the phenomena of "aggregation" in *Drosera* and several other plants. In both processes we have homogeneous, highly refracting protoplasmic masses, which undergo amœboid movements, and are in some unknown way connected with the absorption of nitrogenous matter. In *Drosera* the protoplasmic masses remain within certain cells, in *Dipsacus* they are protruded through the cell-wall.

When we begin to inquire as to the function of the filaments, the answer seems at first to be sufficiently plain, but this is very far from being the case. The connate leaves of the teasel form cup-like cavities, which become full of rain and dew, and in which many drowned insects accumulate. The glands on the lower portions of the leaves are thus exposed to a highly nitrogenous fluid. And since such fluids are known to produce a remarkable effect on the filaments exposed to them, it seems probable that the filaments are in some way connected with the assimilation of food

material. It seems probable that, either with or without the assistance of their filaments, the glands do absorb some nitrogenous matter; for movements of their cell-contents occasionally occur, which can only thus be interpreted. But on account of the rarity and uncertainty of these aggregation changes *within the glands*, but little weight must be allowed to the phenomena as a proof of the absorbing capacity of the glands.

Some other points, however, in the structure of the plant render it almost certain that the connate leaves are specially adapted to serve some useful purpose. Kerner is probably right in believing that the "cups" of the teasel are of use to the plant in keeping off nectar-stealing ants and other wingless insects. But unless this is their only function, it seems probable that the connate leaves have been, to a certain extent, adapted for the capture of insects whose decaying remains are absorbed by the plant. The leaves are smooth and steeply inclined, and form a pair of treacherous slides leading down to a pool of water.

It is worthy of note that the leaves of the first year's growth, which do not form cups, are not smooth, but bristle, with long sharp hairs; moreover in *Dipsacus pilosus* the leaves (of the second year's growth) are not sufficient connate to form cups, and they also are rough with hairs. These facts seem to show that the smoothness of the second-year leaves in *D. sylvestris* is a specially acquired quality. Another special point of structure in *D. sylvestris* may be noted—the prickles on the stem end abruptly above the level of the water in the "cups," and thus avoid supplying a ladder of escape to the drowning victims. Even if we grant from the above considerations that the filaments protruded from the glands are in some way connected with the absorption of nitrogenous matter from the putrid fluid in the cups, we are far from understanding the whole of the problem. For precisely similar *filament-protruding* glands are found on the seedling leaves of *D. sylvestris*, and on the second year's leaves of *D. pilosus*; and as no "cups" are formed in either of these cases, the filaments cannot be connected with absorption of the products of decay. The only view which suggests itself is that the filaments absorb ammonia from the dew and rain. Recent researches have shown that certain leaves have the power of absorbing an appreciable quantity of ammonia, and this fact lends some probability to the view above advanced.

To recapitulate:—Protoplasmic filaments are protruded from the leaf-glands on the teasel; and the only theory

which seems at all capable of connecting the observations made on the properties and behaviour of these filaments is the following. That the glands on the teasel were aboriginally (*i.e.* in the ancestors of the Dipsacaceæ) mere resin-excreting organs. That the protoplasm which comes forth was originally a necessary concomitant of the secreted matters, but that from coming in contact with nitrogenous fluids it became gradually adapted to retain its vitality and to take on itself an abortive function. And that this power—originally developed in relation to the ammonia in rain and dew—was further developed in relation to the decaying fluid accumulating within the connate leaves of the plant.

[redacted]

NOTES AND MEMORANDA.

Sexual Reproduction in Lower Thallophytes.—A couple of fresh instances of the diffusion of a differentiation of sexes amongst the lower Thallophytes have lately been recorded—one in a member of the Chlorophyllophyceæ, another of the Chytridiaceæ, which are of considerable interest.

Polyphagus Euglenæ, Nowakowski.

Dr. Leon Nowakowski describes at considerable length his observations on a Chytridiacean, not indeed new but of which he has discovered the sexual reproduction.[1] After giving a short *résumé* of the observations previously made on the parasites of the Euglenæ, he proceeds to recount his own observations. The distinctions from the genera Chytridium, A. Br., and Rhizidium, A. Br., presented by the subject of his investigations, were so considerable that it became necessary to found a new genus under the name of Polyphagus, and he now calls the form *Polyphagus Euglenæ*.

The author begins his account with the organization of this form. The zoospores, after the cessation of their movements, germinate between the resting Euglenæ; they are at first minute globular cells, colourless, with a strongly refractive yellowish nucleus. They give off four cruciately posed or several (5-6) extremely thin threads radiating around (Fig. D). Each of these becomes more or less elongated until it encounters a Euglena come to rest, whose skin it perforates, penetrating into the green protoplasm; inasmuch as it gradually absorbs this it now acts as a *haustorium* (Fig. D, *e*). One of the germ-threads, namely, that one which first penetrates a Euglena, soon surpasses the others in thickness, assuming the aspect of a tubular stem, the parasite thereby acquiring a clavate figure (C, *e*). The body of the Polyphagus increases in size, owing to the nutriment absorbed from the Euglena, whilst the nucleus grows smaller and finally disappears, some oil-drops and vacuoles taking its place. The rest of the haustoria either remain filamentary or they may elongate and become

[1] Nowakowski: "Beitrag zur Kenntniss der Chytridiaceen," in Cohn's 'Beiträge zur Biologie der Pflanzen,' Bd. ii, Heft 2 (Dresden, 1876) p. 201, t. viii, ix.

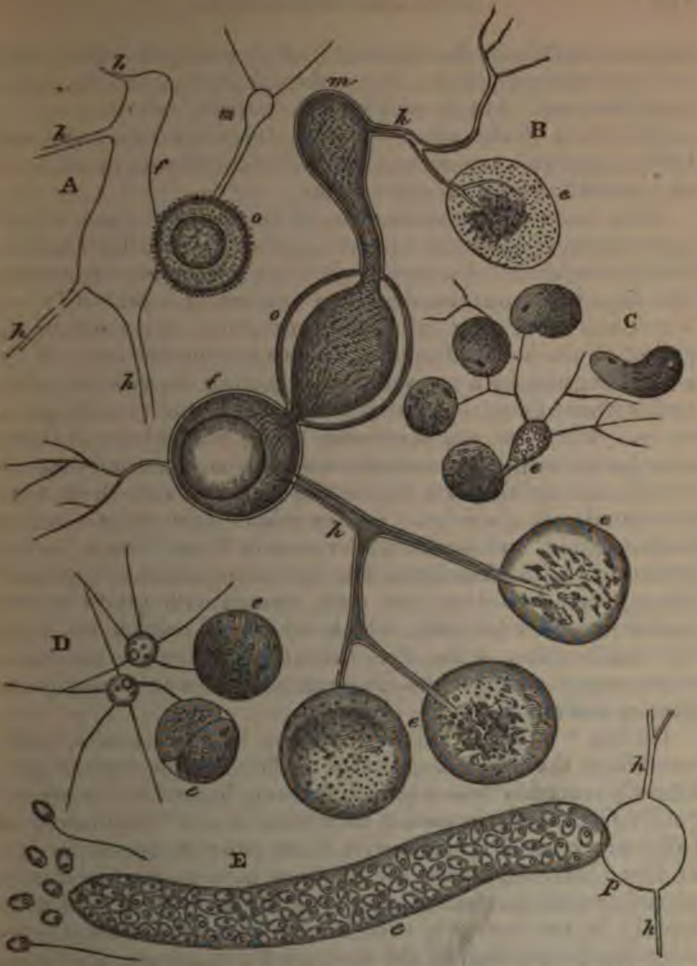
branched in seeking out new Euglenæ. Such as have early penetrated become enlarged and more and more ramified; they may even, though rarely, bore through and penetrate a Euglena behind the first. At the point where they penetrate a Euglena the haustoria show a slight constriction; they may become several times branched in the interior of the Euglena. Sometimes if a zoospore germinate in contact with an encysted Euglena it may push a haustorium into it at the place of contact, so that the latter becomes wholly immersed in the host, and the parasite then appears to sit directly on the Euglena. Not rarely several parasites may attack one and the same Euglena.

The Euglenæ so attacked gradually lose their green pro-oplasm, becoming at first greenish-yellow, and then quite deprived of colour, till nothing is left but brownish granular remains (B, *e*, *e*); even the membrane at last perishes. Some of the brownish remains may finally adhere to the haustoria

The haustoria, especially in a young condition, thus in a measure resemble the pseudopodia of certain Rhizopoda or Acinetæ, but they never alter their figure and very early possess a rigid membrane, which, however, is not coloured blue by iodine and sulphuric acid. Inasmuch as the haustoria are prolongations of the parasite and are without septa, the organism must be regarded as *unicellular*. Its protoplasm contains yellowish oil-drops, coloured reddish brown by iodine, like that of the haustoria, which however, seldom show any oil-drops. The body of the Polyphagus shows considerable variety of shapes, resolvable roughly into two principal forms—the round and the clubshaped, but it may be ovate or elliptic, its variable shape influenced by its search after the host Euglenæ.

Its reproduction takes place both in an asexual and in a sexual way.

Asexual reproduction is by means of zoospores.—These originate in zoosporangia which are produced externally to the parasite-body from the whole of its extruded protoplasm, hence Delpino's designation "prosporangium" is very applicable to the body itself of the parasite (E, *e*). The zoosporangia are thus formed: The whole of the protoplasm of the Polyphagus bores through the cell-wall at a certain point and passes out by a rather large circular opening, making its appearance at first as a little protoplasmic vesicle slowly increasing in volume; when this has very slowly taken up the whole of the protoplasm it forms either a sharply bounded oval or elliptic body directly in front of the opening or it assumes a cylindrical elongate figure. The emerged protoplasmic substance



A. *o*, A fully mature spinulose resting-spore, containing a large oil-drop; *f*, the empty female cell, the haustoria, *h*, *h*, *h*, *h*, represented as cut off; *m*, the empty male cell.

B. Two individuals of different sexes coupled for the fertilisation of the resting-spore, their protoplasm about to become combined, as can be readily perceived by its contraction under glycerine; *f*, the female, *m*, the male individual, each with its haustoria (*h*, *h*) having penetrated the Euglenæ (*e*, *e*); *o*, the oospore, originating as the result of the fertilisation, already surrounded by a thick wall.

C. A young Polyphagus with a short thick haustorium (*e*), having penetrated into a dead Euglena, the remaining haustoria are thin and filamentary, and have also penetrated into Euglenæ.

D. Two germinating zoospores of Polyphagus, each with its strongly refractive nucleus and five radiating germ-threads (haustoria), of which two already somewhat thicker have penetrated into the neighbouring Euglenæ (*e*, *e*).

E. Zoospores making their exit through the terminal opening of the zoosporangium; *p*, prosporangium, *h*, *h*, haustoria (represented as cut off).

contains extremely fine granules, often arranged reticulately, or it contains oil-drops. No enclosing membrane (Haut) can be at first seen, but by and by this becomes evident.

The form of the zoosporangium depends on that assumed by the emerged protoplasm body—oval, elliptic, or elongate and curved; its size too is various.

After some time there originate in the protoplasm of the zoosporangium strongly refractive yellowish "nuclei" around which are formed comparatively large zoospores, their number dependent on the degree of nutriment afforded (E, *e*). These consist of clear colourless protoplasm, surrounding the yellowish nucleus. They finally escape from the apex of the zoosporangium by a not very large opening there originating, and without being surrounded by mucus, and rapidly hurry away. They are comparatively large, elongate-cylindrical, rounded at both ends, sometimes somewhat constricted at the middle, but as they are contractile they can vary their form even to almost globular. In the middle they show a rather large vacuole, and some smaller ones in front. Each carries posteriorly a long flagellum. The author regards the "nucleus" (Kern) as an oil-drop, but, still, treated with glycerine "it appears like a solid body, which no longer refracts the light like oil." After some time (about an hour) the zoospores come to rest amongst the Euglenæ and grow into new parasites as described.

During "culture" these parasites by degrees absolutely annihilate the Euglenæ, so that at last, as the author pertinently remarks, "one might in fact say, but *not* in the sense" "of Dr. Gros" (*nor* in that of the author of the 'Beginnings of Life,' who relies so largely on Dr. Gros, *either*, thinks the writer of this abstract), "that the Euglenæ have become metamorphosed into the parasites." These latter developed, indeed, so rapidly in the author's experiments that they formed considerable layers, but, in the struggle for existence, they ultimately perished for want of nutriment.

Smooth-walled Resting-Spores.—The author proceeds then to describe the sexual reproduction by means of smooth-walled resting-spores. Amongst the individuals two forms present themselves, which may be designated as male and female. The latter are, as a rule, the larger, more or less globular, but becoming irregular or angular owing to the formation of haustoria. The males are smaller, club-shaped, or elongate, even spindle-shaped, of whose haustoria one is developed, as a rule, like a stipes, the rest remaining as filamentary, either free or having penetrated a Euglena. The shapes mentioned of each are, however, subject to some

amount of variation, so that it is sometimes difficult, *before the fertilisation*, to distinguish between them (B).

The process of fertilisation may be regarded as a *conjugation*, since the spore proceeds from the union of the whole protoplasm of two individuals; it is hence a *zygospore*, but also, on account of the sexual differentiation of the parent individuals, it may be designated as an *oospore*.

The male individuals which conjugate may be of any age; even such can be met with in the act of fertilisation which have not advanced in their development beyond a germinating zoospore.

Conjugation begins by the whole protoplasm of the female plant passing out through a circular opening in the same manner as described for the zoospores; hence the body of the female plant behaves as regards the production of the oospore as a "prosporangium." So soon as it has all emerged it forms an oval mass, lying in front of the opening, and it corresponds nearly to a "gonosphere," as yet the author thinks without membrane. Fertilisation takes place by the union of the plasma of a female with the whole of that of a male-plant. The gonosphere comes in contact with the stipes-like haustorium of an adjoining male-plant; its membrane becomes resorbed at the point of contact, whereupon the whole plasma becomes emptied through the haustorium and combines with that of the female—a process requiring several hours to complete.

The zygospore now becomes surrounded by a cell-membrane, at first simple and delicate, afterwards double and thicker—an intine and an exine, the latter becoming yellow, but remaining smooth (B, *o*); the empty walls of both the parent-cells become shut off, remaining, however, in connection with the spore (B, *o*), usually diametrically opposite one another.

It is noteworthy that the stipes-like haustorium of the male often developes lateral ramifications which manifestly, previously to conjugation, serve to absorption of nutriment, subsequently thereto serve, on the other hand, to the emptying of the male plasma. Sometimes minor haustoria are given off from the periphery of the resting-spore. The mature resting-spore is usually oval.

Spinous Resting-Spores.—In the same culture and at the same time that the smooth-walled oospores are produced in the manner described there are formed also sexually-developed resting-spores of yet another kind. These are almost constantly globular, surrounded by a thick double membrane with a yellow-coloured exine and *fine spines* (A). They do

not vary much in size (about 30 mmm.). Their granular contents and large central oil-drops quite agree with those of the smooth spores. The author thinks these are developed in a different way from them. He sometimes noticed that the haustorium of the male came in contact with the wall of the female plant, and as a result of this contact a projection from the body of the female, of an arched figure and already covered with spines, is pushed out, the contents of both gradually flowing thereinto, this projection becoming slowly changed into the perfect resting-spore (A, *o*). The conjugating Polyphagus-individuals, destined to produce spinous spores, like the others, are found in groups; they are usually larger than the smooth-spored, as it were, better nourished. The author leaves in doubt the question whether the smooth- and spinous-spored Polyphagus-forms are to be regarded as two distinct generations, constantly perpetuating themselves (species, races), or as merely unessential variations of the same species, as he did not succeed in rearing the two forms pure through several generations; possibly, he says, the spinous form is the normal, and the smooth-walled form to be regarded as resulting from a less vigorous vegetation.

The author had not succeeded in observing the germination of the spinous spores, although he did that of the smooth. In about a month their oil-drops diminished or were broken into smaller drops; the protoplasmic mass then bored through the wall, and came forth in the manner described for the zoosporangia. Outside the resting-spore it became changed to a zoosporangium, in which, around yellow nuclei, the zoospores originated. Thus the sexually-developed resting-spore of Polyphagus, to a certain extent, admits of being regarded as a "resting-prosporangium."

As to the systematic position of Polyphagus, it, without doubt, belongs to the family Chytridiaceæ, especially as characterised by the mode of origin and structure of its zoospores. During its period of vegetation it consists of a single cell, and its numerous haustoria have an analogy in *Chytridium mastigotrichis*. Since in Polyphagus the zoosporangium becomes separated by a dividing wall from the vegetative cell of the parasite (prosporangium), it might appear as if this organism were bicellular, and belong to the genus Rhizidium, to which, indeed, it was referred as *R. Euglenæ* by A. Braun and Schenk. But the genus Rhizidium is, throughout its life, bicellular, one cell of which is the ramified root-cell, the other becoming the zoosporangium. This distinction at once separates the two genera. They stand, however, in close relationship, and form a special group, the Rhizidieæ,

to which, probably, the author's Obelidium also should be referred. Rhizidium and Polyphagus agree in the mode of the germination of the resting-spores, the whole contents in each coming forth and becoming a zoosporangium. In this respect, too, they call to mind Sorokin's Zygochytrium and Tetrachytrium. In the last-mentioned organism, however, the zoosporangium is formed by the emerged protoplasm only after complete separation from the prosporangium, whilst in Polyphagus the zoosporangium remains always attached to the prosporangium, as already described. In this regard, the mode of development of the zoosporangium in Polyphagus, Zygochytrium, and Tetrachytrium, corresponds to the analogous phenomena shown by the Saprolegniaceous genus Pythium, whilst in their sexual development they approach not less to the Zygomycetæ, most marked in Zygochytrium. In Polyphagus, however, there is a distinction of the sexes presented, characterising the individuals as dioicous, and a new remarkable stage intervening between conjugation and sexual fertilisation is here brought to notice.

Cylindrocapsa involuta, Reinsch.

The alga first discovered by Reinsch,[1] and named as above, is amongst the rarest of freshwater algæ, and curiously enough it is that in it Cienkowski[2] has lately discovered a sexual development.

The alga consists of *unbranched* confervoid filaments, the joints in single series and mostly presenting distinctly laminated walls. Like other similar forms they are collectively enclosed in a common sheath, but here this is very thick and distinctly laminated. According to the more or less vigorous growth their chlorophyllaceous cells are variously figured; in actively growing examples the middle of the cell is occupied by a rather large amylaceous granule, around which smaller ones are disposed; in those less vigorously growing they are densely full of such granules. Young filaments are attached to foreign objects by a colourless basis, but older they are met with free. The upper end of the alga is closed and bluntly rounded.

According to the author's observations, however, this typical habit may be altered in various ways. The envelopes of the cells may become more gelatinous and cell-division ensue in

[1] P. F. Reinsch: 'Die Algenflora des mittleren Theiles von Franken,' p. 66, t. vi, f. 1, 2.

[2] Cienkowski: "Zur Morphologie der Ulothricheen," in 'Mélanges Biologiques tirés du Bulletin de l'Académie Impériale des Sciences de St. Pétersbourg,' t. ix, p. 531.

different directions of space, the cellulose lamellæ, however, still sharply contoured. As in Ulothrix (previously described by the author) Clylindrocapsa takes on too a "Hormospora-stage," the cells in either a filament or in groups. The confervoid habit indeed is maintained only so long as the cell-division takes place transversely; the joints are then cylindrical or discoid, with flat or rounded end-surfaces. If, however, a strong development of the outer laminæ ensues, the plant retains its filamentary form, but it appears as a chain-like concatenation, consisting of green oval cells separated by the intervening laminæ. This is the form or state originally figured by Reinsch, and similar to that in which it has twice presented itself to ourselves. But as described by Cienkowski median and oblique walls may occur; such filaments present numerous expansions or balls, lending to them a gnarled aspect, the whole still surrounded by a common sheath; but lying for a time this disappears, and the cells break up into formless aggregates of two, four, or more cells.

The author had not seen zoospores, but supposes their occurrence doubtless, as he found examples on the side of the glass vessel, which could only have originated from zoospores, as the whole plant is destitute of any spontaneous motion.

This alga possesses antheridia and oogonia. The oogonium (B, C, D) is a globular inflated joint; it consists of contents and wall; the first presents a protoplasmic gonosphere, coloured by chlorophyll, containing numerous starch-granules; it presents at one point of the periphery very often a clear spot. The gonosphere is loosely enclosed by the several (3-6) concentric gelatinous (as it were swollen or expanded) membranes. Such oogonia lie either several tog ether, forming a moniliform chain (E), or they present themselves in the middle of a series of antheridia, or between unaltered vegetative joints, upon which, further on, may abut antheridia (C,D). Cylindrocapsa is thus monoicous. At both poles of the oogonium the coats are produced into a short cylindrical process; adjoining processes are mutually apposed (B). The size of the oogonia varies; it may reach 0·042 mill., the gonosphere 0·024 mill.

The antheridia are discoid or spheroidal little cells, like the oogonia possessing a multilaminated coat (D, *a*); they may form a long series or little groups of pairs; they are often enveloped in twos or fours by numerous laminæ (D, *a*). The contents are clear reddish-yellow. The male-cells (like the vegetative) are formed by binary division of the mother-joint, with the distinction that they cease to grow, remain smaller and gradually assume the yellowish-red colour. Each antheridium developes by division of its contents two spermatozoids.

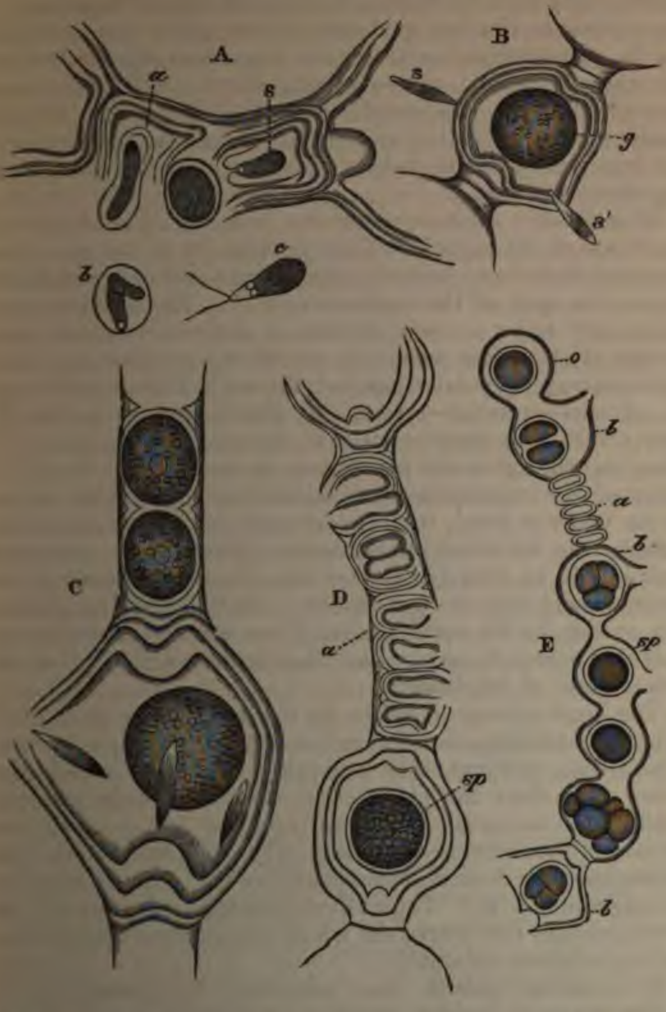


FIG. A. *a*, A spermatozoid making its exit; *b*, two having done so, still enclosed in a gelatinous investment; *c*, a spermatozoid set free; *s*, one still remaining in the mother-cell.

FIG. B. *o*, Oogonium with its coats and showing (*g*) the gonosphere; *s*, a spermatozoid external to the oogonium, and *s'* one caught in the oogonium-opening.

FIG. C. Oogonium with gonosphere and three spermatozoids.

FIG. D. *a*, A series of emptied antheridia, their openings directed to either side; *sp*. oospore.

FIG. E. *a*, Series of emptied antheridia; *sp*. the oospores; *b*, further development of the fertilised (?) gonospheres.

At maturity they are ejected with a jerk; when free, they lie for a while motionless enclosed in their gelatinous envelope (A, *b*). Presently they assume a tremulous motion, at last bursting the vesicle and swimming about. They are protoplasmic fusiform bodies of about 0·015 mill. in length; contents sparing, yellowish-red; at the anterior hyaline point are borne two flagella, below which are two minute pulsating vacuoles (A, *c*).

Shortly after their exit they are to be found in the neighbourhood of the oogonia. The whole cavity of the oogonium becomes pushed out laterally, dissolving and leaving an opening at the apex of the expansion (B, C). The spermatozoids seem now to be no way aimless in their movements, their whole object being seemingly to effect a penetration; with great energy they drive against the wall, their anterior end in advance—retreat—repeat the attack, and so persist for hours. Still only those opposite the opening effect an entrance. They swarm round the gonosphere or swim about in the interior of the oogoniun in its free space (C). This lasts for five or six hours or more, whereupon movement ceases, and they shrink into formless little masses. The author, however, was unable to directly perceive the actual confluence of the spermatozoid with the gonosphere. But all must agree with the author in his opinion that there can be no doubt but that this agrees in nature and significance with similar observed cases of fertilisation.

The next change consists in the appearance of a thick gelatinous stratum directly on the surface of the gonosphere, which soon hardens into a doubly contoured membrane. After some days the chlorophyll with the starch granules gradually disappear, becoming replaced by the reddish-yellow oily substance. In this way we obtain from the gonosphere an oospore, surrounded by the mucous layers of the oogonium (C, *sp*). The author could never see any further development; they lasted the whole autumn and winter without the slightest alteration.

It is curious that in some instances the gonosphores on having become enclosed by the gelatinous envelope began to germinate; they divided into two segments, each then becoming clothed by its own gelatinous envelope, and soon divisions followed just as in the ordinary vegetative joints (E). The author supposes that these still green gonospheres could not have been fertilised, and that only the latter pass over into a state of rest.

From the foregoing the author would place Cylindrocapsa to the Ulothricheæ, and suggests that Ulothrix itself may,

in passing through a similar development-cycle, show hereafter similar sexual conditions, notwithstanding Cramer's and Dodel-Port's record of an act of fertilisation in that genus by means of the fusion of two microgonidia. According to Cienkowski this phenomenon would then have to be otherwise interpreted, especially taking into consideration the circumstance that the microgonidia of that alga are capable of germination without any such "conjugation" having first taken place.

The foregoing memoir is preceded by two others on a "palmelloid" modification of Stigeoclonium and of Ulothrix, in continuation of a previous one by the same author,[1] on a "palmelloid" breaking-up of Stigeoclonium, then increasing, for some time by cell division, their contents breaking up into "microgonidia," which reproduce the filamentous form of the mother-alga; this, in addition to the longer known (now denominated by the author) "macrogonidia." This "palmella zoospore-producing state" he records to have found, too, in Hydrocytium, Coleochæte, and others. *Hormospora mutabilis* and Schizomeris are claimed by the author as but conditions in the palmelloid modifications of *Ulothrix mucosa*. The memoirs are too long even to abstract here. Researches and results such as these would seem to raise the question how far certain protococcoid and palmelloid "forms," looking distinct and regarded as independent, may be but stages in the development-cycle of algæ whose mature and typical forms are "filamentous," and which, although Cienkowski has not, except in Cylindrocapsa, seemingly detected it as yet, may thus probably be found to possess a sexually differentiated fructification.

Separation of the Sexes in Sponges.—F. E. Schulze, in the 'Zeitschrift für Wiss. Zoologie,' gives the result of his study of two species of Halisarca, *H. lobularis* and *H. Dujardini*, carried on at Trieste. Halisarca is a sponge genus without spicules of any kind. It has been made the subject of investigation by several observers, and lately by Carter and Barrois.

Schulze distinguishes as components of the sponge an ectoderm, mesoderm, and entoderm. The ectoderm is composed of ciliated cells, which differ markedly from the ciliated cells of the ciliated chambers in that they have no collar at the base of the cilium. The mesoderm consists of gelatinous homogeneous tissue, in which are scattered nucleated ramified cells in which Schulze has observed all the ordinary

[1] Cienkowski: "Ueber Palmella-zustand bei Stygeoclonium," in 'Botan. Zeitung,' No. 5, Feb., 1876.

phenomena of amœboid movement. The mesoderm tissue is a true connective tissue. There are in the cortical region of the sponge regular systems of branched inhalent and exhalent canals, the main stems of which run almost parallel to one another and at right angles to the outer surface of the sponge mass. The branches of the canals are thickly beset with ciliated chambers,and it is through these chambers,many of which have two canal branches opening into them for the purpose, that the inhalent and exhalent canal systems communicate with one another. One instance was observed in which four canals opened into a single ciliated chamber.

The cortical portion of the sponge is distinguished from a deeper region where there are no ciliated chambers present, but where the generative elements are developed in the mesoderm.

The Halisarcas and also a number of other sponges examined by Schulze, viz. amongst siliceous sponges *Reniera informis*, *Spongilla lacustris* and *S. fluviatilis*, and amongst horny sponges *Aplysina aërophoba*, in all of which this observer has clearly made out and investigated the spermatozoa are diœcious. All former observers, as *e.g.* Eimer and Haeckel, have found in the species examined by them spermatozoa and ova in the same sponge. Both male and female elements are developed out of rounded cells with dark granulated contents occurring in the mesoderm, but the origin of which was not determined. Both elements become developed in cavities formed in the mesoderm tissue, which are clad with a layer of polygonal endothelium cells. The spermatozoa have an elongate, egg-shaped head, a smaller front part of which, is marked off from the hinder larger part by a constriction. The tail of the spermatozoon, which is 0·08 mm. in length, is set on to the head on its side and not at either of the ends. Out of the one rounded cell a large mass of spermatozoa are developed, and out of a similar single cell only one ovum. Hence, as in many other animals, the single egg is equivalent to a mass of spermatozoa.

The segmentation of the ovum is, as was determined by Carter and Barrois, a complete one, but sometimes irregular. The segmentation cavity is first to be observed when sixteen cells have been formed. It was found impossible to keep the larva, which is equally ciliated all over at the time of its emergence, alive long enough to observe its further development. Schulze was no more able than Barrois has been to observe an invagination or formation of a gastrula.

The above remarks refer to the structure of *Halisarca lobularis*. In *H. Dujardini* the ectoderm both on the outer

surface of the sponge, and clothing the canals is devoid of cilia, which are present only in the ciliated chambers. The species differs also in other histological details from *H. lobularis*, such as in possessing branched connective tissue fibres in the mesoderm like those of Medusæ; the mode of communication between the inhalent and exhalent canal systems is also different, and takes place by means of irregularly sac-shaped or even sometimes somewhat branched ciliated chambers.

Schulze has also described in the last number of the 'Archiv für Mikrosk. Anat.' a new hydroid polyp which lives invested by sponge-colonies. He terms it *Spongicola*. It is to this parasite or a similar form as suggested by Carter, that Eimer's observation of thread cells in sponges (Renieridæ) is due. Prof. Allman has described in 'Nature,' July 30th, 1874, a hydroid of similar habit under the name of Stephanoscyphus.

On the Structure of Striped Muscle-Fibres. By Cand. Med. WILHELM BIEDERMANN, from the Physiological Institute at Prague ('Vienna Sitzungsberichte d. k. Akad.,' Juli, 1876). —The interstitial substance between the primitive muscle-fibrils, discovered by Kölliker, has by some recent histologists —Sachs, R. Arndt, and especially J. Gerlach—been regarded as intimately connected with the intramuscular nerve-terminations. Arndt regards each individual fibril as continuous with the nerve of its bundle, *i. e.* the so-called muscle-column (Kölliker), and J. Gerlach asserts that the isotropous substance of a muscle-fibre is directly connected with the intramuscular nerve. Gerlach arrived at this conclusion from the study of muscle-fibres treated with gold solution. Under this reagent there appear within the muscle-fibre granular or rod-like structures arranged in a more or less distinctly linear manner (Spenkelung) so as to resemble at some places filamentous structures of a varicose appearance quite like primitive nerve-fibrils that had been stained with gold solution.

Biedermann in the above paper shows that that dotted appearance (Spenkelung) can be invariably produced by staining muscle-fibres of crustacea, insects, or vertebrata, while they still possess the power of contracting, in 1 per cent. solution of chloride of gold. The fibres are placed in this solution for five to ten minutes, having been previously kept in a somewhat dilute formic acid; they are then brought into a watchglass of water and a few (one or two) drops of formic acid, where they are kept for twenty-four hours in a dark place.

After this time the muscle-fibres have assumed a deep red colour, they are then washed in water and mounted in glycerine. Each muscle-fibre treated in the above manner appears under the microscope permeated by innumerable dark (red to black) dots or rods, which at some places are so arranged that the impression of continuous varicose fibrils is produced. Now, Biedermann proves 1, that these dots or rods are not due to isotropous substance, but to a reduction by the gold salt of interfibrillar matter; 2, that they are in no way connected with the nerve-terminations. These latter Biedermann describes in accordance with Kühne and contrary to Gerlach, who maintains that there exists an intravaginal nerve-network. Biedermann ascertained these facts while examining the muscle-fibres of vertebrata, insects, and crustacea; in the thorax-muscles of Hymenoptera, and especially in those of Bombus, the interfibrillar substance, on account of its great amount, is particularly easily observed.

REVIEWS.

1. *Compendium of Histology; twenty-four lectures.* By Professor HEINRICH FREY. Translated by GEORGE R. CUTTER, M.D. London: Smith, Elder and Co.
2. *A Course of Practical Histology.* By E. A. SCHÄFER, Assistant-Professor in University College, London. Same publishers.
3. *A Course of Elementary Practical Physiology.* By M. FOSTER, M.D., F.R.S., Fellow of and Prælector in Physiology in Trinity College, Cambridge; assisted by J. N. LANGLEY, B.A. Macmillan and Co.

The English student of the minute anatomy of animals has no reason to complain at the present day of a want of manuals, guides, and handbooks, from which he may make a choice at the commencement of his studies. So far as precise directions can be given in printed pages, he may find all that he need know in order to develop into an accomplished histologist, in the "practical course" of Professor Schäfer, supplementing what he will there find as to *methods* by reference to descriptive treatises such as Quain's 'Anatomy,' where the objects to be seen

when these methods are used are carefully described and figured. Professor Schäfer's book is remarkable for the care with which it has been prepared, and derives special value from the fact that the author is himself constantly engaged in testing and expounding by practical demonstration to his pupils the importance and significance of the modes of studying the tissues which he recommends. The book is illustrated with numerous good woodcuts of bits of useful apparatus.

Amongst works descriptive of the tissues, the translation of Professor Frey's 'Compendium' cannot fail to be popular with students. It is not an exhaustive work, but runs rapidly over the subject, omitting the doubtful and dwelling on the essential and well-established teachings of histologists. It is copiously illustrated, and the style throughout is lively and interesting. The translator has adhered so closely to the words of the original that he has occasionally failed to give the author's meaning.

We have placed Dr. Michael Foster's work in the list at the head of this page because in it he adopts a method of teaching histology which we are inclined to think is the right one, when it can be carried out. Dr. Foster deprecates pure histology and the making of endless beautiful preparations. He prefers when once the student has learnt to use his microscope and mastered the outlines of the anatomy of the tissues, to make his further study of microscopic anatomy advance *pari passu* with the experimental study of the properties and functions of tissues and organs. There can be no doubt that it is only by close association with the life-giving hypotheses of either physiology or of evolutional morphology that a healthy cultivation of the refinements of modern microscopy is possible.

PROCEEDINGS OF SOCIETIES.

Dublin Microscopical Club.

19th October, 1876.

Section of 'Chert' exhibited, with remarks on its origin.—Professor Hull, F.R.S., exhibited some thin sections from the upper Chert zone of the Carboniferous limestone which is remarkably persistent throughout the range of that formation from Sligo on the north-west to Co. Carlow on the south-east, and Cork and Kerry on the south-west. These sections, taken from different localities, tended to confirm the opinion of those who believe that the chert is pseudomorphic, and has replaced the limestone of the original rock. Not only are corals and crinoids, which must have originally been formed of carbonate of lime, now frequently found preserved in silica (Chert), but, as these sections showed, obscure traces of these and other forms are brought out with the aid of polarized light, under the microscope. In other cases the sections of corals and crinoids themselves exhibit very beautifully the infiltered silica filling up the interiors of the skeleton, as well as the skeleton itself, of these structures.

Assuming, then, that the silica has replaced the original calcareous rock, the question arises at what period this replacement has taken place. Mr. Hull considered it probable that the period was that prior to the deposition of the overlying Yoredale shales, when the organically-formed limestone rock was exposed to the waters of the open sea, and was acted upon—first, by waters charged with carbonic acid, followed by others containing silica abundantly in solution.

Carmine-stained sections of the electric organ and Skin of Malapterurus electricus, were exhibited by Mr. B. Wills Richardson.—Referring to the account given in Cuvier's 'Histoire Naturelle des Poissons,' and to Owen's 'Anatomy of the Vertebrates,' Mr. Richardson gave several details of their histology as to which he found these authors, as well as Rudolphi, silent. The skin is beset with numerous beautiful tree-like processes, between which occur short conical processes. These he at first supposed might be fungoid in nature, though he had afterwards satisfied himself that they were dermal.

Pigment-cells of dark brown tint were very general in all the sections.

Sphæridia of Stomopneustes variolaris and of Laganum depressum, exhibited.—Mr. Mackintosh exhibited the detached sphæridia of *Stomopneustes variolaris*, Lamk., and also a section of the corona of *Laganum depressum*, Lesson, showing one of these organs *in sitû*. They were first described in 1871 by Prof. Lovén, in the Öfversigt af Kongl. Vetenskabs Akad. Forhandlingar,' No. 7 (translated in the 'Annals and Mag. Nat. Hist.,' Oct., 1872).

Chlamydospores of Nyctalis parasitica, exhibited.—Mr. Pim exhibited a transverse section of the gill of *Nyctalis parasitica*, which grew abundantly on decaying agarics (chiefly Russulas) in the vale of Avoca. The section showed the remarkable Chlamydospores described by de Bary (in 'Botanische Zeitung,' 1851), which appeared to originate by free cell-formation from the hyphæ, and to consist of a short piece of hypha enclosing an oval cell with a distinct nucleus. The ordinary agaric-form of fruit, according to de Bary, has not been found in *N. parasitica*.

Botrytis dichotoma, new to Ireland, exhibited.—Mr. Pim likewise showed the mould *Botrytis dichotoma*, Corda, found by Corda near Prague, but which does not appear to have been previously recorded as British. It consists of thick threads, pure white, once or twice dichotomously forked. The spores occur all over the hyphæ, are spherical and each on a distinct though very short pedicle, somewhat like those of Acremonium. It was found on decaying tulip-stems at Monkstown, Co. Dublin.

Dactylium macrosporum, exhibited.—Dr. W. M. A. Wright showed examples of *Dactylium macrosporum* from vale of Avoca, where it grew in one spot abundantly on *Polytrichum commune*, forming a patch like a heap of light snow.

Occurrence of Spondylosium pulchellum in a stipitate and attached condition, for the first time so observed.—Mr. Archer exhibited examples of the rather rare desmid *Spondylosium pulchellum*, ejus, which presented the unexpected fact that this form occurs *stipitate*, although this was the first occasion he had ever noticed this condition. Probably this stipitate condition is really the normal one, and the form as usually found, consisting, it may be, of a concatenation of a considerable number of cells down to a very few, three, two, or even solitary joints, merely represents so much of a filament dissociated from its original stipes—as occurs, indeed, with so many other similar algæ. Thus the mode of occurrence of this species is comparable to that of certain diatoms. Here, indeed, the stipes connecting the filament (of greater or less length, 2-3 joints, to 30-40) with the supporting plant (in this instance a small-sized barren Œdogonium) is reduced to a very short cylindrical cushion, of about one half the length of a joint or cell of the Spondylosium. As is to be expected, there is no difference whatever between the basal or terminal cell of such a filament and any of those along its length,

all being alike, except of course where interstitial growth of new semi-cells might be going on, in the ordinary characteristic manner. It needs not, therefore, to point out that this attachment by a gelatinous cushion-like stipes is in no way comparable to the mode of attachment of young conjugate forms by means of a "root-cell;" the basal cell as mentioned does not form a "root-cell" by any means, but is quite equivalent to each and all of the remainder of the perfectly independent cells going to make up the "filament." Indeed, in this genus, destitute of any little connecting processes between the concatenation of cells characteristic of Sphærozosma, it is probable that the cells are mutually held together by a very short intervening gelatinous *pad*, comparable to, but much smaller than, the stipes by which the whole is attached to foreign objects.

Optic Vesicles in Chick.—Dr. Macalister exhibited for Prof. Cleland a mounted preparation of a young chick about thirty-six hours old, showing the condition of the optic vesicles at that stage.

Exhibition of rare (some very striking) Desmidian Species.—Mr. Archer exhibited a number of exceedingly rare Desmidieæ from a recent gathering made in Connemara, including the (so to speak) colossal forms of Staurastrum: *St. arctiscon* (Ehr.) Lundell, *St. ophiura*, Lundell, *St. sexangulare*, Bulnheim, *St. longispinum*, Bailey; other not less rare and interesting forms, if smaller and less striking than these fine objects, occurred in this rich collection.

16*th November*, 1876.

Odontodiscus Hibernicus, O'M., *exhibited.*—Rev. E. O'Meara exhibited a slide of diatoms taken from stomachs of Ascidians cast up by recent storms on the shore of Dublin Bay. Several forms of interest occurred in the material, and especially *Odontodiscus Hibernicus*, O'M., a new species described by Mr. O'Meara in his 'Report on Irish Diatomaceæ' ('Proc. R. I. Acad. Science,' ser. 2, vol. ii, p. 271, pl. 27, f. 7).

Roots of Utricularia montana, exhibited.—Dr. Moore exhibited roots of the South American *Utricularia montana*. The roots exhibited had grown over the margin of a flower-pot in which the plant is cultivated in one of the conservatories at Glasnevin, and were clinging to the bare exterior of the pot. Notwithstanding they were beset with miniature bladders, as perfectly formed as those on our British species, though these were scarcely perceptible to the unaided eye; when viewed through a three-quarter-inch objective, they are both pretty and curious objects.

Transverse section of the Spine of Porocidaris purpurata, Wy. Thomson, was exhibited by Mr. Mackintosh; the section, however, did not present as remarkable features in its internal structure as one would have expected from the striking external appearance of the species. Its principal peculiarity was the very slight external crust, which had simple tubes traversing it.

Mr. Mackintosh was indebted to Professor A. Agassiz for the portion of the spine from which the section was taken.

The Pseudo-electric Organ of the Ray.—Mr. B. Wills Richardson exhibited transverse and longitudinal sections of the so-called electric or pseudo-electric organ of the Ray, and observed that at one time the organ was considered by some very distinguished observers to be structureless. This, to him (Mr. Richardson), was surprising, when he considered the complicated beauty of the sections, and the facility with which they could be made. The organ was one of those bodies occasionally met with the whole arrangement of which would escape observation were the sections too thin. He (Mr. Richardson) had some that were cut to such extreme tenuity with the freezing microtome, that portions of the cells into which the organ was subdivided were shaved off. It truly was most complicated. Examination of the longitudinal sections would show that the organ was divided into numbers of cells of somewhat oval shape, and apparently of uniform capacity. The transverse or cross sections, on the other hand, showed that these cells, so uniform when viewed in the longitudinal slice, varied in shape when cut transversely, or at right angles to the long axis of the organ. Each cell seemed complete in itself, and was arranged thus:—There was first a layer of capillaries that formed, as it were, a deep vascular wall, which occupied or bulged into about half the cavity in the longitudinal direction. This could be seen distinctly in the longitudinal sections only. Removal of the capillaries disclosed a layer composed of broad, loosely interlaced fibres, formed of connective tissue, crossing which in various directions were seen flat branching fibres of extreme tenuity, possibly nerve cords. Finally, and apparently covered by this coarse fibrous structure, there was a delicate translucent membrane, in which vast numbers of exquisitely fine fibres ramified and formed a loose network, in the meshes of which were scattered minute and for the most part oval, granular, darkish corpuscles, that gave off numerous radiating, inosculating fibres, of relatively great length. Those bodies were probably connective-tissue corpuscles. This delicate translucent structure was composed of two, or possibly more, layers, in one of which the stellate processed corpuscles were chiefly situated, whereas in the other there were imbedded, at very regular intervals, nucleolated corpuscles, having well-defined margins. The greater number of these were round, the remainder oval; the round reminded one of the nuclei seen in the delicate membrane of the cells of the electric organ of the Malapterurus he exhibited at the last meeting of the Club, but the nucleolus of each of the latter appeared to be more distinct. The nucleus itself, however, was smaller than that seen in the Ray. The remaining walls of each cell, with which the structures so described were connected, were composed of close-set fibrous tissue. The sections were stained with carmine and mounted in glycerine. Mr.

Richardson concluded by observing that he had some other sections of the organ in a weak osmic-acid solution, and if it led to any further disclosures concerning the structure of the cells, he would exhibit them at a future meeting of the Club.

Extremely minute Cosmarium-form with zygospore, held to be a new species, exhibited.—Mr. Archer showed conjugated examples of an extremely minute Cosmarium, so minute, indeed, that it would seem to merit the name, and most likely keep it,of *C. minutissimum*. The zygospore is ellipsoidal or oblong, dark tinted, of purplish or bronze-like hue, thick walled, but contents green. The Cosmarium itself resembles several, perhaps most so *C. pusillum*, Bréb.; but minute and readily overlooked as it may be in itself, it is doubtless quite a distinct thing. But more on a future occasion.—Mr. Archer likewise showed the conjugated state of *Didymoprium Borreri*, rarely found in that state, common as is the species; Ralfs' figure is very graphic.

Exhibition of Oocystis setigera, Arch.—Mr. Archer likewise exhibited examples of *Oocystis setigera*, ejus; he had never found this seemingly well-marked form except in a restricted locality in Connemara, and these were from the same site.

Microgromia mucicola, Arch., *n. s.*, *exhibited.*—Mr. Archer also exhibited the rhizopod he had named *Microgromia mucicola* (seemingly a distinct form from *Microg. socialis*), this time nestling in the mucus of *Cosmocladium Saxonicum*, de By.; he had never found it before except imbedded in the mucus of the equally rare alga of similar habit—his *quondam Dictyosphærium constrictum*.

21*st December*, 1876.

New Species of Chlorochytrium (Cohn), *exhibited.*—Professor E. Perceval Wright showed examples of a new chlorophyllaceous parasitic alga inhabiting the living tubular envelopes of several species of Schizonema—and doubtless forming a new species of Cohn's interesting and lately founded genus—Chlorochytrium—the type species inhabiting *Lemna trisulca*, and named by its discoverer *Chlorochytrium lemnæ*. Like that species, the present reproduces by zoospores, which impinge (often in great numbers) on the diatom filaments, gradually penetrating them, and growing therein into new plants. The fully formed plant is subglobular, or depressed in figure, the endochrome disposed in parietal masses, and often showing strings of plasma, nearly colourless, radiating from the nucleus. Dr. Wright is working out the history of this highly interesting form, and he hoped ere long to be in a position to describe it at length with illustrations.

Helicomyces roseus, exhibited—Mr. Greenwood Pim showed examples of *Helicomyces roseus*, a rare mould, which he had found on the cut stump of a tree in Fassaroe demesne, Co. Wicklow. It does not appear to have been published anywhere as British, not appearing in either Cooke's 'Manual' or in 'Grevillea,' as

far as he was aware, although both Mr. Phillips and Mr. Vize had informed him that they possessed specimens of it. It forms a delicate pinkish-grey bloom on the surface of the wood, consisting of numerous short threads, bearing spiral heads of rather oblong spores. It differs from *Helicomyces tuberosus*, figured in 'Grevillea' (vol. iii), in having longer heads, which are in length about twice the diameter of the spirals; in having the spores in a flat, not a helicoid, spiral; in having the spores themselves more oblong than square; and in its pink rather than white colour to the naked eye.

A Vertical Section of the Frontal Lobe of the Cerebrum in Young Chick, prepared by Professor Cleland, was exhibited by Dr. Macalister.

Floeberg Dust, exhibited.—Dr. Moss, late of H.M.S. 'Alert,' showed samples of "Floeberg Dust," collected on the late Arctic Expedition, and containing remains of diverse microscopic organisms—Diatomaceæ, Radiolaria, Peridinium sp.—some from a mass of interesting material he had yet to work up.

Sections of Erectile Tissue, exhibited.—Mr. B. Wills Richardson exhibited several sections taken from the penis of a child aged three and a half years. They formed that portion of the organ situated between the glans and the scrotum, and were made with the freezing microtome, stained with Beale's carmine stain and mounted in glycerine. Mr. Richardson drew particular attention to the shape of the urethra in the specimens. It was not tubular as some persons imagined; and in the portion of the organ which afforded the sections was a transverse slit or fissure, with shorter fissures leading from it. That disposition of the canal showed that it was plicated in the longitudinal direction, an arrangement apparently to allow of its expansion for the free ejaculation of the semen. In none of the sections could a helicine artery be discovered in the corpora cavernosa.

Tooth of Echinothrix turcarum.—Mr. Mackintosh exhibited a cross section of the tooth of *Echinothrix turcarum*, Schynvoet; also some of the detached prisms, covered with "soldering particles," and a separate "flabelliform process" of the same. The principal point in which the tooth-structure of this species differs from that of Echinus, so well described by Salter ('Phil. Trans.,' 1861), is in the absence of a keel on the internal aspect, the tooth being simply grooved, and the consequent reduction in the amount of the prismatic tissue, which occupies a comparatively narrow zone in the middle of the tooth.

New form of Donkinia.—Rev. E. O'Meara showed what appeared to be a new form of Donkinia, found in stomach of Ascidians cast on the shore of Dublin Bay by recent storms. Valves short and broad; height ·0035″; breadth ·0066″; broad and rounded at ends; striæ coarse, oblique; median line diagonal, approaching closely to the margin at either end, and in an opposite direction. On *f. v.* slightly constricted in the middle; lobes nearly linear till near the ends; striæ obvious.

Prothallus of Gleichinia rupestris, with antheridia, was shown by Dr. Moore. This formed a very pretty object viewed with a ¼ in. objective, the long narrow prothallus being of a beautiful vivid green colour, contrasting well with the brown antheridia.

Test of a new Species of Euglypha, exhibited.—Mr. Archer showed some examples of the *test* of a Rhizopod *à priori* to be referred to Euglypha as a new species. He regretted ho had not observed the living examples. It was somewhat irregular in figure, but of a generally broadly subfusiform figure, truncated in front, and somewhat drawn out posteriorly and bluntly rounded, quite hyaline, the facetted appearance very difficult to make out. There is no other Euglypha attenuated behind, all the species being broadly and pretty equally rounded. Of course, without seeing the living animal, one could not feel positive as to the correct location of this form in the genus Euglypha; but there could, probably, be very little doubt about it. The test, however, appeared to be of, seemingly, a more yielding character than that of an ordinary member of this genus, say *E. compressa* or *E. alveolata*. Mr. Archer would meantime name this form *Euglypha sacciformis*.

[redacted]

MEMOIRS.

RÉSUMÉ *of* RECENT CONTRIBUTIONS *to our* KNOWLEDGE *of* "FRESHWATER RHIZOPODA." Part IV. Compiled by WM. ARCHER, F.R.S. (With Plate XIII.)

Lecythium hyalinum, Hertwig et Lesser[1] (Plate XIII, figs. 1, 2),

is the name applied to a form identified by the authors as equivalent to that named *Gromia hyalina* by Schlumberger,[2] and by Ehrenberg and Fresenius[3] called *Arceilla hyalina*, and again by Schneider identified as *Difflugia enchelys*. No doubt these authors were each wrong in referring such a form to any of these genera. For that reason, seemingly, Hertwig and Lesser conceived they were compelled to institute a new genus, therefore named as above; Cienkowski[4] accepts this genus. But it occurs to me to suggest that, just as in Schulze's form referred to Gromia (as *G. granulata*), there is little, if anything, to separate either from the genus Plagiophrys, Clap. et Lachm. The test of *Lecythium hyalinum*, Hertwig et Lesser, is roundish, pellucid, membranous (structureless), thin—according to Hertwig and Lesser not flexible, but according to Cienkowski it is flexible—according to the former bilaterally symmetrical, but according to the latter only accidentally so, with a short neck. The body-mass completely fills the test, anterior portion granular and vacuolar, posterior homogeneous and bearing a nucleolated nucleus; pseudopodia filiform, homogeneous, much branched, sometimes anastomosing. (See fig. 1, showing a dorsal or posterior view. Fig. 2, after Cienkowski, perhaps doubtfully identical, shows a lateral view.) There seems

[1] Loc. cit., p. 117, t. iii, f. 8.
[2] Schlumberger, 'Ann. d. Sc. Naturelles,' iii ser., vol iii, p. 255 (1854).
[3] Fresenius, 'Abhl. d. Senckenb. Gesellsch.,' Bd. ii (1858).
[4] Loc. cit., Bd. xi, p. 117 to vi, f. 5, 6.

nothing here requiring a new genus distinct from Plagiophrys. Possibly, too, the same would apply to the following:

Chlamidophrys stercorea, Cienkowski[1] (fig. 3).

Except that in the form so named as a new genus and species the body-mass is not in close apposition to the test (possibly of more importance than might at first sight appear), this comes also close to Plagiophrys. It was found in a curious habitat, that is, amongst fungals on dung.[2] The author considers it to be identical with the *Difflugia enchelys* (Schneider). The body-mass and the pseudopodia seem to be "Euglyphan," so to say, that is, presenting a posterior homogeneous region with nucleolated nucleus (sometimes two, or even more, nuclei), an equatorial granular zone, and an anterior vacuole-bearing region, in which, for the most part, digestion is carried on; but it possesses a hyaline *structureless*, ovoid, or sub-reniform test, with a short, terminal, or somewhat lateral node, and the body presents a rather thick pseudopodial stem. The pseudopodia are numerous, though but slightly branched, and are non-granuliferous (fig. 3).

Cienkowski found several individuals clustered together in conjugation, which he interprets, however, as the expression of the result of an act of division. The example pushes through the opening of the test a protoplasmic expansion, in which at first no nucleus is noticeable, but in which it subsequently becomes developed—according to the author, independently of the mother-nucleus. When a test becomes formed, which at first appears closely applied to the body, the individual thus newly produced may part from the "mother-animal," but, as in Microgromia; with copious nutriment, this form in the same way produces clustered colonies, the openings of the tests directed to the common central point of union.

During his "culture" the author often found individuals with two or three or more nuclei. Their origin seemed to be independent of the original nucleus (though called by the author "Mutterkern"), at least he never saw any division of it. But the significance of this fact remained unknown to him.

This form further undergoes a resting-state. The whole body-mass makes its exit from the test, which, after assuming

[1] Loc. cit., p. 39, t. vii and viii, f. 73-89.

[2] The words in Cienkowski's memoir (p. 39) which run . . . . . "der meist bewohnenden Pilze" should surely be . . . . . "der mist-bewohnenden Pilze."

a globular form, becomes covered by a thick membrane. The finely granular contents of the cysts, generally lying in clusters, becomes so dark that no insight can be gained of their histological nature. Schneider described a fourfold division of the contents, which Cienkowski was unable to confirm.

Platoum parvum, Eilh. Schulze[1] (fig. 4),

is the name given by that author to a marine form, which again he makes the type of a new genus and species. However opinions may differ as to the propriety of relegating the preceding form (*Chlamidophrys stercorea*, Cienk.) to the older genus Plagiophrys, there seems, at any rate, no doubt but this form and the preceding at least are congeneric, in which case the name Platoum would have the priority. In the present form the Euglyphan body-mass is suspended within a structureless hyaline membranous test, the latter differing in its form from that of Cienkowski's *C. stercorea*. The author regarded it, as it were, intermediate between Cyphoderia and Gromia, but the former is wide apart by reason of its areolated test, whilst the forms referred by this author to the latter genus seem mainly to belong truly to Plagiophrys, from which this and the preceding form seem to differ only as pointed out.

The form is compressed, in the broader view it is ovate, often a little curved, one front arched or convex, the other flat or a little convex; the aperture of the test is round, its border a little thickened. The body-mass with its posterior nucleolated nucleus, middle granular zone, and anterior hyaline region, often with one or two pulsating vacuoles and long, slender, very slightly branched, non-granuliferous pseudopodia (fig. 4); all are quite like those of Cyphoderia or Euglypha, but the structureless, simply membraneous test separates it from these genera (if they, *i. e.*, Cyphoderia and Euglypha, indeed, should ultimately be maintained as distinct).

Its test is in that respect similar to that in Hyalosphenia (Stein); but the Euglyphan, that is to say, filamentary, slightly branched, and more or less tufted (not Difflugian, that is, lobose) character of the pseudopodia completely separates it therefrom.

And the reference to Hyalosphenia causes a momentary retrogression in order to seize the opportunity here to apologise to Mr. Tatem for my having overlooked that

[1] Loc. cit., Bd. xi, p. 115, t. vi, f. 1-4.

that experienced observer and enviably excellent draughtsman had already described a form[1] under the name of *Difflugia ligata*, which certainly belongs here, and which extremely probably is identical with either one or other of the forms referable to Hyalosphenia (or, indeed, these, nay, all three, may be possibly found to be identical when better known). Stein's description (1854), unaccompanied by any figure, is too brief to judge by; but if Tatem's form coincides with Schulze's that should, without doubt, be denominated *Hyalosphenia ligata*, (Tatem), Schulze. If, on the other hand, it coincides with Stein's, it would be but a synonym of *Hyalosphenia cuneata*, Stein. In a letter to me Mr. Tatem remarks that he cannot regard the difference of the test sufficient to remove such a form from Difflugia. In this I cannot agree with him. Singularly enough, it is since I last wrote that I had an opportunity to see my first Hyalosphenia; it quite agreed with Tatem's excellent figure in the main, except in two points: first, in that my example was just one half the linear dimensions of his (being $\frac{1}{600}''$ long in place of $\frac{1}{300}''$); and, second, that it shows (what is not delineated by him) a distinctly nucleolated nucleus, posed as usual at about the posterior third of the body. The four stolon-like sarcodic prolongations by which the body-mass was attached to the inner posterior surface of the test were quite as he shows them. But in this circumstance the form is not singular, many other rhizopods showing them in greater or less number. In my example the single lobose (scarcely branching) pseudopodium was also characteristic. Surely, indeed, there must be deep-seated and inherent "generic" differences between those groups of forms (*genera*, in my sense) which wholly eschew all extraneous aid in the build-up of their tests, which are a pure secretion product only, and other groups of forms which, with a marvellous power of selection and adaptation, must "cast about" to alight upon suitable building material; nay, with what "specific" uniformity one such form sticks about it those foreign "stones," of the most rugged character, in the most rugged fashion, whilst another chooses very much smoother ones, and seemingly lays them on with what, by comparison, may be called "mosaic" regularity. And so on. Again, surely the hyaline continuous membrane-like test of Hyalosphenia is quite a different thing from that of Quadrula, composed of, as it were, distinct panes of glass, coherent by their margins in such a way as to build up and

[1] 'Monthly Microscopical Journal,' vol. iv, p. 313, t. lxviii, f. 1.

bring about the quite characteristic form of the test in the two species known. Further, in reply to Dr. Wallich's objection as to *Arcella vulgaris*, with its remarkable and unique test, how can one without violence refer such to one and the same genus as those "stone-gathering" Difflugians above referred to, not to speak of those others (still, indeed, retained in Difflugia) with so remarkably differing tests from those of *D. pyriformis*, *D. oblonga*, &c., for example, as those of *D. spiralis*, *D. carinata*, *D. triangulata*, &c.?

Dr. Wallich seems to think, in a letter with which he since favoured me, that the remarks in my last communication, which were mostly only a reproduction in English of Hertwig and Lesser's, touching on the views so well known to be entertained by him as regards the propriety of regarding *Arcella vulgaris* as merely a form or species of the genus Difflugia, were calculated to convey an erroneous impression of what he really had expressed, or to indicate that he had not already grasped, even considerably before the authors referred to, the true structure in Arcella. Those authors were surprised that, if he had so grasped the wide distinctions, rendering their possessor, indeed, unique, he should still relegate Arcella to Difflugia as a mere subform; and one would gather from their remarks that they were inclined to fancy that from the very fact of his doing so he could scarcely have truly realised the distinctions after all. There can be no doubt indeed that he did; and I confess, for my part, that I feel surprised they should appeal to him in vain. Whilst, indeed, I should myself feel very sorry if, through oversight in any way, any references of mine should seem, even remotely, to deprive Dr. Wallich of the great credit which is his due, I can still only wonder that observations so exact and experience so great as his should have led him to views and conclusions so divergent from those of most recent observers in this field.

Gromia paludosa, Cienkowski (fig. 5).

A seemingly remarkable form is described under the above name by Cienkowski. He, however, characterises it as destitute of *nucleus*, which one may almost *à priori* assume to be erroneous. It seems otherwise from his description to possess the general appearance and structure of a Gromia, but the considerably elongate and pronounced pseudopodial stem is not apical and in a line with the axis, but lateral. The test is delicate and colourless, oviform, with but a very slightly elongate "neck." The pseudopodial stem takes

[1] Loc. cit., Bd. xii, p. 32, t. vi, f. 44-47.

origin to one side at some distance down from the apex; the body is thus bilaterally symmetrical; that aspect whence the pseudopodial stem springs the author would speak of as its "dorsal" and the opposite as its "ventral" aspect. The "oral" aperture is likewise somewhat below the apex and to one side of the principal axis, hence, seen in "side view," this form shows there a somewhat deep inlet or sinus in which lies the pseudopodial stem between the body and the test. (See lower part of fig. 3.) The reddish or colourless contents are described by the author as if in constant rotation; his examples contained several non-contractile vacuoles and sundry incepted objects.

The only mode of increase observed by the author consisted in division. The first indication of this (as he describes) was, the appearance of a new pseudopodial-stem at the base of the example and the perforation of the test at this place. At the same time the test along with the contents becomes more and more deeply constricted, the isthmus thus being formed becomes more and more drawn out, until it at last gives way. The two new "tailed" examples gradually draw in these appendages.

Of this curious form the author saw no mode of encysting indicated, though such of course is to be expected.

The author does not say if there were any appearance after the "drawing in" of the "tails," of the filling up of the aperture in the test. May one here venture on the suggestion that this is really not a form appertaining to Gromia at all, but a true amphistomatous rhizopod, and that the fresh perforation and emission of a new "pseudopodial stem" as described by the author is really not founded on fact, but that the perforation was there always, although in the examples studied by him there were at the time—possibly until the constriction had begun to be formed—no pseudopodia issuing therefrom? This indeed in the first-known amphistomatous form, *Amphitrema Wrightianum*, is occasionally to be seen, that is, a tuft of pseudopodia may be evident only from one extremity, and indeed in almost every case the pseudopodial stem is more strongly pronounced, and the tuft of pseudopodia is notably more copiously given off, from one of the apices than from the other. At the same time most of the author's figures show a necklike prolongation only at one end, but see his fig. 45 (l. c.), where an example is shown during constriction, and with a well-developed "neck" and pronounced "oral" aperture at *both* extremities.

If that were so, that is, that Cienkowski's *G. paludosa* were really an amphistomatous form, the supposition might

be hazarded that an increase by constriction as described by him may be at least one mode of increase for Amphitrema as well.

But supposing *G. paludosa*, Cienk., to be really amphistomatous, and therefore not a Gromia, and holding to the general view and method of classification adopted by Hertwig and Lesser (with which I would quite coincide), owing to the test of their form being destitute of foreign particles, and in fact "structureless," it could not be relegated to the genus Amphitrema (as yet, indeed, of but one species only), covered as is the test there by foreign particles (though mainly confined to the outer edge). Were, in fact, my conjucture correct this form would seem then to fall under my own proposed genus Ditrema,[1] founded for the form named *D. flavum*, to be referred to further on.

Euglypha ampullacea, Hertwig et Lesser (fig. 7).

The test of this form is flask-shaped, drawn out into a neck, length 0·07, breadth 0·04—0·05; diameter of mouth 0·02—0·025 mm. Hexagonal plates comparatively very minute, elongate, arranged in twenty-four spirals, gradually becoming longer as they come to form the inflated part of the test; there are often a few irregularly scattered spines. The mouth is beset by twelve "teeth," each sitting upon two of the plates, their outer margin showing two emarginations. (See fig. 7.)

Cyphoderia truncata, E. Schulze[2] (fig. 6.)

This form was found in sea water, and indeed in the same gathering as occurred in the author's *Platoum parvum*. It differs seemingly from the common *Cyphoderia margaritacea* mainly in the straight, not curved, axis of the test, hence the test-opening comes to be exactly transverse to the longitudinal axis, not oblique thereto. The contour and size of the test in *C. margaritacea* is well known to be variable, hence the occurrence of a straight form would not, I fancy, be surprising, and would seem to suggest the generic separation thereof from Euglypha on that account, even though the hexagonal plates be so very much smaller than in most Euglyphæ, and not drawn out in the longitudinal direction, is scarcely justifiable. In fact, the obliquity of the frontal aperture has its parallel in the much *smaller* form, and with considerably *larger* hexagonal plates, *Euglypha pleurostoma*, Carter.[3]

[1] "Minutes of Dublin Micr. Club," in 'Quarterly Journ. Micr. Science,' vol. xvi, p. 340, and vol. xvii, p. 103.

[2] Schulze, loc. cit., Bd. xi, p. 113, t. v, f. 21-22.

[3] 'Ann. and Mag. of Nat. Hist.,' 2 ser. vol. xx (1857).

Test incrusted with foreign particles.

Pleurophrys compressa, Eilh. Schulze (fig. 9).

Of this form the author had as yet found but a single example (in a ditch at Rostock). Its length was 0·075, breadth 0·04 thickness, 0·01 mm. Elliptic compressed without neck, mouth truncate; in side view test of lanceolate outline. The author saw (notwithstanding the opacity caused by the coating of siliceous arenaceous particles) the large round nucleus shimmering through. The author found also *Pleurophrys fulva*, mihi; of the correctness of his identification of this form there can be no doubt.

Pleurophys lageniformis, Eilh. Schulze[1] (fig. 8),

is a form found by the author in sea water; its length was 0·06, greatest breadth about 0·04 mm. It is elliptic, drawn out into a neck, mouth truncate, in end view circular; pseudopodia numerous; the author did not perceive a nucleus; of its presence there can, however, really be no doubt.

On the LYMPHATICS *and* PARENCHYMA *of the* THYROID GLAND *of the* DOG. By E. CRESSWELL BABER, M.B. Lond. (With Plate XIV.)

THE following is a concise account of a research carried out under the direction of Dr. Klein, and described at length in a paper read before the Royal Society in January, 1876.[2]

Previous Investigations on the Structure of the Thyroid Gland.—The results of these may be gathered from the writings of Henle,[3] Kölliker,[4] Verson,[5] and Frey.[6] According to these authors the thyroid gland consists of numerous vesicles embedded in, and supported by, a stroma or framework of connective tissue, containing blood-vessels, nerves, and lymphatics.

The *stroma* is directly continuous with the capsule of

[1] Loc. cit., Bd. xi, p. 125, t. vii, f. 6-8.

[2] See 'Philosophical Transactions,' 1876, vol. 166, pt. 2, p. 557, *et seq.*

[3] 'Handbuch der Systematischen Anatomie des Menschen,' 1866, vol. ii, pp. 535—541.

[4] 'Handbuch der Gewebelehre,' 5th ed., 1867, pp. 480—482.

[5] Stricker's 'Human and Comparative Histology,' Sydenham Society's translation, by H. Power, vol. i, pp. 370—372.

[6] 'Das Mikroskop.,' 4th ed., 1871, pp. 232 and 283.

connective tissue investing the gland, from which strong trabeculæ pass inwards, dividing the gland into lobes, and from these again finer septa originate, which subdivide the lobes into lobules. In this way the thyroid gland of man "is divided into primary and secondary segments, the line of division between which is recognisable by slight furrows" (Verson). The connective tissue lying between the several gland-vesicles is, according to the same author, very sparing in quantity, and sometimes even it is difficult to discover between the walls of contiguous vesicles a few fibres accompanying the capillaries. Henle finds the vesicles partly separated by fine connective-tissue septa, and partly in direct contact with one another. The *gland-vesicles* (*Drüsenbläschen,* Kölliker) are described as closed globular bodies, consisting of a very fine homogeneous membrane (*membrana propria*), lined by a single layer of epithelial cells (Kölliker, Henle, Verson). Frey does not believe in the presence of a *membrana propria.* The epithelial cells are described by Henle as flattened cells, containing circular nuclei, and resembling a layer of epithelium. According to Kölliker they are polygonal, finely granular, transparent cells, each with a single nucleus. Frey, again, alludes to them as flattened, cylindrical, nucleated cells. Finally, Verson lays stress on the fact that the cells in the fresh condition are always somewhat higher than broad.

The cavity of the vesicle is described as occupied by a clear viscid fluid (Kölliker, Frey), slightly tinged with yellow, and containing much albumin (Kölliker). Henle speaks of the contents as clear and becoming converted by the action of alcohol into a firm, somewhat shrunken coagulum.

The *lymphatics* of this organ have been last studied by Frey, who gives the following account of them, as quoted by Henle (*loc. cit.*):—"The large lymphatics covering the capsule of the thyroid gland take their origin from a rounded network which surrounds the secondary lobules. From these there branch off finer arborescent canals for the primary lobules, to surround them with perfect rings or with arches more or less complete. From these, again, a few finer canals dip down among the individual vesicles, and end in blind extremities." Frey himself (*op. cit.*) describes the lymphatics as quoted above by Henle, excepting that he does *not* confirm the statement of their ending in blind extremities.

The present research was undertaken with the object of investigating the lymphatics of this organ; in the course of it, however, it became necessary to study carefully the vesicular and intervesicular tissue of the gland, and in so doing

certain cells were observed in the latter, which, it is believed, have not hitherto been described. The subjects of this paper may, therefore, be treated under two headings:—1. The Lymphatics, and 2. The Parenchyma. Before considering these, however, it will be necessary to say a few words with regard to the general structure of the thyroid gland of the dog, as observed in this research.

First, with regard to the *stroma*. In the dog, as is well known, the thyroid gland consists of two separate portions, situate on either side of the trachea. Each of these forms, apparently, a single lobe, which is divided into lobules, more or less distinctly, by processes of connective tissue passing inwards from the surface of the organ, where they are continuous with the connective-tissue capsule surrounding the gland. These bands of connective tissue run chiefly with the blood-vessels and gradually diminish in size till between the individual vesicles it is often impossible to say that there is any stroma present. On the whole the stroma appears very sparing in quantity.

The Vesicles.—Between the different ramifications of the stroma are seen the vesicles with their walls, consisting of a single layer of cells arranged like an epithelium, and usually known as "epithelial cells." These commonly present a square or wedge-shaped outline, though their shape varies in different preparations and in different parts of the same specimen. They are usually higher than broad; sometimes, however, they present a more or less flattened appearance, probably the effect of the reagents (fig. 1). Under certain circumstances these cells present a more or less triangular or crescentic outline, of which more hereafter. Their cell-substance is finely granular, and they are each provided with a single spheroidal nucleus. With regard to the existence or not of a *membrana propria* outside the epithelial cells I am not in a position to make any definite statement.

Contents of the Vesicles.—The contents of the vesicles consist, in addition to a small quantity of a pellucid substance sometimes present, of a peculiar material, which shrinks away from the walls of the vesicle and forms a solid mass in the centre (fig. 1, *c*). In sections stained with picrocarminate of ammonia it appears as a finely granular substance, of a more or less bright yellow hue, contrasting with the red colour of the walls of the vesicles.

In specimens coloured with hæmatoxylin, on the other hand, it presents the aspect of an opaque, grey, or greyish-violet mass, which is generally uniform, but sometimes finely granular in appearance.

I. The Lymphatics.

Methods.—The methods of investigation adopted were as—

(1) *Injection with Berlin Blue.*—The thyroid gland of a freshly-killed dog was injected *in situ* with a solution of Berlin blue by the method of puncture with a subcutaneous syringe. When sufficiently injected the gland was removed and hardened, and sections of it were stained and mounted in balsam.

(2) *Injection with Nitrate of Silver.*—The gland was injected in a similar manner with a one eighth per cent. solution of nitrate of silver instead of Berlin blue.

Throughout this research the glands examined were those of adult dogs only.

Characters and Distribution.—The appearances presented by the lymphatics may be considered under two heads:

1. *Macroscopic Appearances.*—On injecting one of the portions of the gland with Berlin blue solution by the above method the following appearances presented themselves:—The whole organ swelled up and a fine network of injected vessels appeared on the surface, which could be distinctly seen with a hand-lens; at the same time lymphatic vessels became injected, running from the gland in a direction upwards and downwards. The former, after forming a plexus above the gland, gave off two principal branches, the one running upwards and inwards over the front of the windpipe, the other upwards and outwards, and terminating in a large lymphatic gland situate under the upper part of the sterno-mastoid muscle. The vessels running downwards from the gland emerged at the lower and inner extremity of the organ, and soon united to form a single vessel, which, taking a course downwards and inwards in front of the trachea, entered a small lymphatic gland situate in the median line over about the sixteenth ring of the trachea. Injection in a similar manner with nitrate-of-silver solution also showed a network of lymphatics on the surface of the organ.

2. *Microscopic Appearances.* — Traversing the gland chiefly in a longitudinal direction, and accompanying the larger blood-vessels and septa of connective tissue are numerous *lymphatic vessels* of considerable size. They not uncommonly surround the arteries which they accompany, as represented in fig. 1, and even completely invaginate them, so as to represent "perivascular lymphatics." These vessels are in direct communication with the network of lymphatics already described on the surface of the organ. They are

provided with valves, and their walls are formed by a layer of endothelium, the cells of which are elongated, and have a somewhat sinuous outline. Many of these cells appear to be provided with two or even three oval-shaped nuclei.

Coming off from these vessels, and traversing the gland in all directions, are *numerous lymphatic tubes*, of very varied size and shape. The larger ones run principally between groups of vesicles, and are in direct communication with smaller ones, which pass between individual gland-vesicles. The latter (the "few finer canals" of Frey), in a well-injected specimen, are seen to be numerous, and are frequently noticed partially, and not uncommonly completely, surrounding individual vesicles. The tubes vary very much in size and form—in fact, they appear to adapt themselves accurately to the intervals left between the vesicles. This being the case, as might be expected, the diameter of a tube rarely remains constant for any distance; and where the intervals left between the vesicles are larger the tubes expand into *lymphatic spaces*, having the most irregular shape.

The lymphatic tubes, then, both large and small, together with the lymphatic spaces, form a dense rounded network of freely anastomosing canals, which permeates the entire substance of the gland. *In no case have I seen any indication of the lymphatics terminating in blind extremities*, and can only attribute such an appearance to an imperfect injection. The distinctly tubular character of the tubes, as well as the form of the spaces and tubes generally, are best seen in specimens injected with Berlin blue. In perfectly injected parts of silver preparations a continuous layer of endothelial cells is seen lining both larger and smaller lymphatic tubes and spaces (see fig. 2). The endothelial cells are somewhat elongated, and present an irregularly sinuous outline. They form a delicate membrane, which in a thick section can be seen following accurately the walls of the vesicles and covering them like a thin veil.

Once familiar with the appearances in preparations in which an injection has been successful, the walls of the lymphatic tubes and spaces may be recognised between almost all contiguous gland-vesicles in parts where the injection has not penetrated. They appear in this case as two fine dark wavy lines, studded at intervals with deeply-stained, staff-shaped nuclei. This appearance, attributed to the lymphatics, may in some instances be produced by capillary blood-vessels. Judging, however, from specimens in which the lymphatics are injected, it is probable that we have to do with such vessels, although it is not possible to distin-

guish the nucleated membrane forming the wall of a capillary blood-vessel from that of a lymphatic.

Contents of the Lymphatics.—On examining a specimen injected with Berlin blue and stained with picrocarminate of ammonia, by far the greater part of the cavity of the lymphatics is seen to be filled with a granular material of a more or less bright yellow colour. The blue injection occupies the peripheral portion of the lumen, forming bands of colouring matter between the wall of the vessel and its contents (see fig. 1, *b*). On examining the lymphatic tubes some of them are seen to contain this granular material; the greater part, however, in a well-injected specimen, are filled with blue injection. It is probable that the injection first entering the smaller tubes forces their contents, or at least a part of them, onwards into the larger tubes and lymphatic vessels. From the relation existing between the injection and the contents of the vessels I am led to the conclusion that during life the contents are of a *viscid consistence;* for if, at the time of the injection, the contents were fluid, the injection on entering the vessels would either force the contents of the same before it or would mix with them. The injection, however, being performed *immediately* after death, the contents could not have had time to coagulate, and as the blue does not mix with the contents, but forms a separate layer between them and the wall of the vessel, it follows that the contents must during life have been more or less viscid in character.

In sections stained with logwood the contents of the lymphatics usually present a uniform appearance, but are sometimes finely granular. They stain of a greyish-violet colour.

In addition to this material the lymphatics sometimes contain a few hyaline drops.

II. PARENCHYMA.

Besides the stroma, lymphatics, blood-vessels, &c., between the vesicles, there is another tissue, to which, as far as I am aware, no reference is made by authors on this subject. To this tissue it is proposed to give the name of "parenchyma," on the supposition that it is possibly analogous to the parenchyma of the testis described by various authors.

Characters of the Parenchyma.—On examining with a high power sections of the gland stained with hæmatoxylin and mounted in balsam, numerous cells are seen differing markedly in size and shape from the epithelial cells amongst which they lie. These cells are usually more or less rounded

in appearance, and considerably larger than the adjacent epithelial cells. Their cell-substance is finely granular, and they are each provided with a single large nucleus. Sometimes these cells present an irregular outline, and are at the same time smaller, as if the cell-substance had shrunk up round the nucleus, leaving a space between it and the surrounding structures. In other parts of the specimens, however, the cell-substance presents a regular rounded outline, and is in contact with the neighbouring elements. The nuclei of the parenchymatous cells are round or oval in shape, and present a well-marked outline. They are larger than those of the epithelial cells, and do not stain quite so darkly with hæmatoxylin. In their interior are seen several nucleoli. The parenchymatous cells are met with either alone or in groups. In the latter case several frequently appear to be situate in a common cavity, which they do not fill out (see fig. 4). With regard to their relation to the walls of the vesicles, these cells may occupy at least *four positions*.

1. They are found, either singly or in groups, *external* to the vesicles, and separated from their cavity by a layer of *normal epithelial cells* (*i. e.* epithelial cells as described above).

2. Other parenchymatous cells, also situate in the intervesicular spaces, are seen to be separated from the cavity of an adjoining vesicle by a layer of *flattened epithelial cells*, the latter presenting a concave surface to the parenchymatous cells.

3. Some parenchymatous cells are seen encroaching on the layer of epithelial cells to such an extent that they are only separated from the cavity of the vesicle by a *thin membrane*. They lie, as it were, in a cup formed by the flattened epithelial cells (see fig. 3, *c*).

4. In other cases these cells are seen lying in a cup formed by the epithelial cells, and in which the flattened epithelial cells, or the membrane, separating the parenchymatous cells from the cavity of the vesicle have given way, thus placing the parenchymatous cells in *direct communication* with the contents of the vesicle (see fig. 4, *b*). In this, as in all other situations described, the cells may be single or several together, apparently occupying a common cavity.

Lastly, rounded cavities formed by flattened epithelial cells and communicating with the cavity of a vesicle are sometimes seen in *an empty condition*.

The above appearances represent the different stages of a process which may be summed up as follows :—*The paren-*

chymatous cells originate in the intervesicular tissue external to the walls of the vesicles; from some cause (inherent movement or growth of cells behind them) they exert pressure on the wall of an adjoining vesicle; the cells of this become flattened out or absorbed to a greater or less degree, and finally give way, allowing the parenchymatous cells to escape into the cavity, and to form a constituent of the contents of the vesicle.

The distribution of the parenchyma through the gland appears tolerably uniform, though probably its cells are more numerous between the small than between the large vesicles. As above mentioned, in some places they are numerous and form groups, whereas in others they appear only thinly scattered on the walls of the vesicles. Having been observed in all thyroid glands of the dog which were carefully examined, they must be regarded as normal and constant structures.

From the small vesicles, which they frequently resemble in size, the parenchymatous cells may be distinguished by the presence of the nucleus and by their being less highly refractive.

Resemblance between the contents of the Vesicles and those of the Lymphatics.—The description of these two substances given in a previous paragraph indicates the close resemblance existing between them. There are several reasons for considering them identical.

1. *The general Appearance and Staining with Reagents.*—In specimens stained with picrocarminate of ammonia and mounted in balsam they *both* appear granular and of a more or less bright yellow colour. In sections stained with logwood they *both* present generally a uniform, sometimes a finely granular aspect, and stain of a greyish-violet colour.

2. *The Consistence.*—The reasons for considering the contents of the lymphatics to be during life of a *viscid consistence* have been given above under I. The contents of the vesicles are described by Kölliker and Frey as consisting of a clear *viscid* fluid; and, as far as I have seen, there appears no reason to doubt this assertion, although I have not directly proved its accuracy.

From these facts it appears that the contents of the lymphatics are *morphologically identical* with those of the vesicles, and they give a strong reason for suspecting that the two materials are identical in other respects.

It is of material importance to remember that in all but one or two cases examined, most of the vesicles, as well as the lymphatics, contained the material above described; and

it is further important to bear in mind that the material in the lymphatics completely fills and even distends the vessels, without containing any formed corpuscles; the material cannot, therefore, be lymph. Hence it is reasonable to think that *one, possibly the chief, function of the thyroid gland* is the formation, within the vesicles, of a material which is transferred from these by the lymphatics to the general circulation, there to serve some purpose in the animal economy as yet unknown. The close relationship existing between the lymphatic tubes and the walls of the vesicles, together with the abundant distribution of lymphatics, both within and without the gland, appear to lend support to this view.

Frey (*op. cit.*, p. 232), speaking of the glands formed of closed vesicles, mentions this theory, and alludes to it as "a very insufficient explanation." He may well do so, seeing that he gives *no reason* in support of it; for neither Frey, nor any other author I have consulted, alludes to the contents of the lymphatics, still less to the *identity* (*morphological, at least*) *existing between the contents of the vesicles* (where the material is supposed to be *formed*) *and those of the lymphatics* (by which it is supposed to be *carried off*); nor do they give any other ground in support of this view.

NOTE.—*May*, 1877.—In addition to the above structures in the thyroid gland of the dog, bodies of considerable size are frequently seen, usually on the surface, which differ greatly in structure from the rest of the gland. From a comparison of their structure with that of the gland in the embryo, I am led to believe that they are probably portions of the organ whose development has been arrested before the formation of vesicles has taken place. It will suffice to mention these bodies here, leaving a description of them to a future time.

The MINUTE ANATOMY *of the* ALIMENTARY CANAL. By HERBERT WATNEY, M.A., M.D. (With Plate XV.)

THE following is an abstract of a paper published in the 'Philosophical Transactions,' vol. 166, part 2. The research was commenced and carried on under the direction of Dr. Klein for the first fifteen months; during the last year it was continued independently. The paper was read in January, 1876. It is illustrated by forty-three drawings, most of them having been made by means of the camera lucida.

The paper is divided into three chapters, the first of which treats of the minute anatomy of the mucous membrane of the intestine and the method of fat absorption; the second of the minute anatomy of the mucous membrane of the pyloric end of the stomach; and the third of the minute anatomy of the mucous membrane at the point of transition between the stomach and the intestine.

The first chapter begins with a statement put forth as a proposition, which the author seeks to demonstrate in the rest of the chapter. The statement is that—

The mucous membrane of the intestine is pervaded everywhere by a reticulum similar to and continuous with that found in the follicles of Peyer's patches. This reticulum is situated among all the other elements which are contained in its meshes. This is true of the epithelial cells, the muscle-fibres, the cells of the parenchyma and of the endothelial plates of the membrana propria, of the blood-vessels and lymphatics. It is by this reticulum that the fat is absorbed, and by this reticulum that the fat finds its way into the lymphatic vessels, and probably also into the blood-vessels.

After this follows a long history of the previous researches on the subject. It is shown that at first the lacteals were supposed to open on the surface; then, when the epithelium was discovered, it was imagined that there were minute pores in the borders of the epithelial cells through which fat could pass. The view that was held by some observers of the fat pressing in everywhere among the tissue is also mentioned, as are the later and important researches of Basch, Erdmann, and Zawarykin, on absorption, and the anatomical facts discovered respectively by His, Teichman, Recklinghausen, and Debove.

After the history a short account is given of the different

views which various observers have held about the small cells among the epithelium.

The methods which were employed are then given; chromic acid and chloride of gold were used as hardening reagents; osmic acid as a means of distinguishing the position of the fat particles.

The structure of the epithelium and the nature of the tissues found among the epithelial cells are next described.

It was found, in contradistinction to the research of Thanhoffer, that the epithelial cells are closed, and it is also shown that they have no processes stretching into the mucosa. Attention is drawn to the fact that most authors who have asserted that the epithelial cells have processes have worked too exclusively with the intestine of the frog, and seem to have been unaware of the extreme length of the epithelium in that animal, and of the different lengths of the epithelium in different parts of the intestine, and even in a single villus (see Pl. XV, fig. 1).

It was found that among the epithelial cells small round cells are seen similar to the lymph-corpuscles of a lymphatic follicle (see l. c., fig. 1), and in addition to these cells groups of young epithelial cells, which are called "epithelial buds" (see fig. 6). It is also shown that a reticulum, similar to and continuous with that which exists in the lymphoid follicles and in the villi, can be traced everywhere among the epithelium of the intestine, the reticulum appearing in vertical sections of the epithelium as fine, almost thread-like, processes, continuous with the dark line on which the epithelium appears to rest. This dark line (see fig. 1, *r*) is due to the sectional view of the connective-tissue reticulum which lies surrounding the epithelial cells. In transverse sections of the epithelium the reticulum appears as star-shaped bodies united by processes.

As regards the membrana propria of the villi, appearances are found somewhat similar to those figured in the long-lost sight of research of Eberth, that is to say, there is a definite membrane (not, as the older authors held, a greater condensation of retiform tissue), the membrane being formed chiefly of cells, as was pointed out by Debove; and it is also shown that the endothelial cells of which it is composed are very similar to the cells forming the upper part of the villus (see *e*, fig. 1). It is also demonstrated that a reticulum continuous with that of the villus, holds in its meshes the endothelial-like cells of the membrane.

The tissue of the villus is composed, not, as has been so often described, of branched connective-tissue corpuscles or

of branched cells of the retiform tissue, but of a reticulum which does not differ from that which is found in the lymphoid follicles, consisting of a network of fibres with thickened nodes. The reticulum contains cells in its meshes. These cells are of two kinds, lymph-corpuscles and large, somewhat flattened, spheroidal cells arranged as an endothelium (see figs. 1 and 3); they are very similar to the endothelium of the blood-vessels, lymphatics, and membrana propria. The lymph-corpuscles are found chiefly at the lower part of the villi and the spheroidal cells at the upper part. It is, however, distinctly stated that a gradual transition can be traced from the lymph-corpuscles to the endothelial-like cells of the upper parts of the villi. In the mucosa no fibrous tisue can be found, as has been figured by some authors.

The mode in which the muscles terminate in the rabbit's colon and in the villi of many animals (see *m*, fig. 1) is described. It is found that the bundles of muscles separate into individual fibres, which, running up to the surface, are apparently attached to the cells of the membrana propria. It is demonstrated, however, by oblique and cross sections of the muscularis mucosæ, that every muscle fibre is surrounded by the reticulum, and that this reticulum is continuous with that of the rest of the mucosa. It is by this reticulum that the muscle bands running up towards the surface are attached to the cells forming the membrana, or, more correctly, to the reticulum surrounding the cells forming the membrana.

It is shown that in some animals the chyle-vessel is at least half surrounded by a membrane of muscle-fibres dovetailing into one another. The importance of this fact appears to be that any theory which attempts to prove the absorption of fat by means of branched connective-tissue-corpuscles connected to the chyle-vessels, &c., must, in such a case, be evidently at fault; and if it were not for the knowledge of the delicate reticulum pervading and holding in its meshes all the other tissues of the villus including the muscle-fibres, this one fact would make great difficulty in the comprehension of the process of fat absorption, unless we followed Frerichs, Donders, Funke, and Dönitz, in supposing that the fat presses in everywhere in a cloud-like form.

The blood- and chyle-vessels are shown to be composed of a membrane formed of endothelial plates, *a delicate reticulum being found between the individual endothelial cells* (see *r*, fig. 2), this reticulum being continuous with that of the rest of the mucosa, and forming the adventitia to the vessels. There is a difference between the adventitia of the arteries and veins, so that we may always recognise the

arterial character of the minute arterial capillaries, even where there are no involuntary muscle-fibres surrounding the vessel.

The author concludes the anatomical part of this chapter by asserting that he has demonstrated that there is everywhere a reticulum holding all the elements of the mucosa in its meshes; *he finds that the reticulum must be considered not only as a network of threads, but as forming, at any rate in some places, membranous investments.*

The next part of the chapter is an attempt to prove the second part of the proposition, namely, that it is by the reticulum that fat is absorbed. First, as regards absorption by the reticulum among the epithelial cells, it is found that in horizontal sections of the epithelium, or in teased preparations where the epithelium is separated *en masse* from the rest of the tissue, fat-granules are arranged in lines between the epithelial cells (see fig. 4) in preparations where the epithelium is cut vertically; although the appearances are not quite so satisfactory, yet lines are seen between the epithelial cells. If the SEPARATE epithelial cells are viewed in teased preparations they are found APPARENTLY to contain fat, but this is explained by the fact that the reticulum always breaks off with the epithelium, and that the fat is really in the reticulum, and not in the epithelial cells.

The following conclusion is therefore drawn:

From the foregoing observations there is proof that the fat travels by the reticulum between the epithelial cells, but there is no decisive evidence that fat-granules are absorbed by the epithelial cells.

The fact that in the villus the reticulum filled with small fat-granules is so similar to that seen in preparations hardened in chromic acid (compare fig. 3 and fig. 5), sustains the following conclusion:

The fat travels by the reticulum which is found everywhere among the other elements of the mucosa.

The only difference in the two appearances in figs. 3 and 5 is that the reticulum is broader in fig. 3; this is always the case in preparations which have been hardened in Müller's fluid and osmic acid (see figs. 8 and 9).

Then some space is occupied by an attempt to give all the situations in which the reticulum has been seen, with the various properties which have been ascribed to it; the author considers that it was a similar reticulum which was seen in the salivary glands and pancreas among the epithelial cells and described as nervous tissue by Reich and Pflüger, as connective tissue by Boll, as intercellular capillaries by

Gianuzzi and others, as a continuation of the cell membrane by Heidenhaim, and as a cuticular formation by Von Ebner. That it was seen among the epithelium of Brunner's glands by Schwalbe, who considered it secretion-capillaries with a coagulation of their contents; in the mammary gland by Gianuzzi and Falaschi; in the "rete Malpighii" of the skin as small branched bodies deeply stained by gold; in the epithelium of the intestine by Fles and Erdmann, who deemed it cement substance; in the same situation by Zawarykin, who described it as the borders of the cells; in the serous membranes by Klein, who described it as pseudo-stomatous tissue and who considered it of great importance in absorption; that possibly it was noticed among the endothelium of lymphatic vessels by the name of stomata by His and Recklinghausen, and as stigmata by Arnold; in the alveoli of the lung by Sikorsky, Klein, and others, Klein having figured it as interepithelial nucleated branched cells in connection with the connective-tissue-corpuscles of the mucosa and thus in continuity with the lymphatic vessel. It is also shown how injections have been forced into it by Carter in many places, as has been done much more completely by Arnold, and that by a natural injection Thoma obtained a precipitation in the same tissue. Injections have also been forced into it by other observers, as Basch, Wittich, Zawarykin, Sikorsky, and others.

In concluding this chapter the writer expresses his view that absorption is not a purely mechanical process, the fluids being pressed along a semifluid reticulum, but that the reticulum takes an active part in the process, and he quotes an observation of Busk and Huxley to a similar effect.

The second chapter, on the minute anatomy of the pyloric end of the stomach, commences with a short history of previous researches, which mentions Professor Lovén's discovery of lymphatic vessels in the mucous membrane, and Rabe's discovery of the unequal length of the glands of the stomach of the horse.

It is found that in those animals, as the dog and horse, which have very compound glands, the stomach is thrown into wave-like elevations of alternating long straight tubes with long straight plicæ villosæ and short wide tubes with folded sides and contracted plicæ villosæ, and that these appearances are very similar to those which Ebstein has given as representations of the stomach of a dog in stages of sponge feeding and vegetable feeding respectively.

The glands are described as consisting of wide cylindrical

tubes or "DUCTS," lined by an epithelium continuous and identical with that of the surface; these ducts dividing two short branches, and into each of these branches two or three small branching tubes open. These small branching tubes are called the "COILED TUBES."

It is shown that the epithelium of the surface is open in certain stages of secretion only, as was described by Todd and Bowman.

Observations are next recorded on the germination of the epithelium, as seen from hardened specimens. It is found that there are four different phenomena.

A. Many of the epithelial cells covering the surface are found to contain nuclei in a state of division, and this division is transverse, oblique, and longitudinal. B. Small cells are seen at the base of the epithelium, and these cells are of two kinds, lymph-corpuscles and conical or rounded cells, the latter differing in every respect except size from the former. C. Short, broad epithelial cells are also found; and, finally, D, the epithelial buds or groups (see fig. 6), composed of two or three, or even more cells arranged very much like a bud. The same features are seen in the small round or conical cells, in the short broad cells, and in the epithelial buds. These features are a spherical nucleus as opposed to the oval nucleus of ordinary epithelium, and a finely granular protoplasm of the cells, which is not readily stained by hæmatoxylin. The conclusions which are drawn are—that the epithelial cells divide, that the small round cells are products of their division, that these cells rise up and form the short broad cells, and that they in turn by division form the "epithelial buds." The epithelial buds are found in situations where they cannot be explained by foldings of the epithelium, and they occur in young and old animals.

Attention is drawn to the fact that there is an intercellular substance uniting the epithelial cells of the surface of the stomach, which is acted upon by staining fluids in quite a different manner to that in which the reticulum is affected.

The membrana propria is found to resemble that of the villi.

The blood-vessels in the plicæ villosæ are shown to be enclosed in perivascular spaces, these spaces being formed of endothelium; towards the surface, where the blood-vessel, run parallel to the surface, the upper wall of the perivascular space is formed by the membrana propria of the plicæ villossæ an arrangement similar to that which has been described by Boll in the salivary glands, and Ludwig and Tomsa in the testicle. Probably these perivascular spaces are the lym-

phatics which Lovén injected by the method of puncture. The muscle bands run up by the side of the perivascular spaces and end in a very similar manner to that which has been already described in the account of Chapter I.

A fine reticulum is described as existing among the epithelium of the coiled tubes. It is shown that if in a vertical section one of the coiled tubes is found running vertically and is viewed from the outside, so that the epithelium is seen in an optical horizontal section, the reticulum appears as small branched bodies united by processes (see fig. 7). If the section cut one of the tubes obliquely, we get appearances similar to fig. 8. In both figures the nuclei of the epithelial cells can be seen between the threads of the reticulum. Fig. 9 gives the appearances presented by a section made from the same tissue hardened in Müller's fluid and osmic acid. It will be noticed how much broader the reticulum appears than in fig. 8, and it explains the view Schwalbe took, that this appearance is due to a network of canals.

It was found that whatever be the state of digestion, the nuclei almost always exist as flattened discs lying at the lower part of the cells. At times, indeed, the nuclei were found to have a spherical form, but never over a considerable tract of the stomach. During digestion the cells are granular and stain more readily than during inanition. The writer, therefore, differs in opinion very materially from Ebstein; first, in regard to the contraction of the mucous membrane of the stomach; secondly, in the shape of the nuclei of the cells of the coiled tubes in various states of digestion; and thirdly, in describing an interepithelial reticulum.

A third form of nucleus is described and figured which was sometimes met with, the nucleus appearing to be undergoing some form of vacuolation.

It was observed that, in young animals, the surface epithelium is apparently completely filled with fat, as had been previously noticed by Bruch and Kölliker; whereas in fully developed animals, while no fat is found in the epithelium of the surface, the epithelium of the ducts and coiled tubes appears cloudy with fat, especially in animals whose stomachs contain bile. No explanation is offered of these appearances, the author reserving that to another paper.

Chapter III describes the continuity of Brunner's glands with the coiled tubes of the stomach.

First, a short history is given which shows how nearly Cobelli arrived at the same results. He, however, thought

that there are two kinds of glands in the pyloric end of the stomach of man, mucous and acinous, and concluded that the acinous glands of the portio pylorica may be considered as a continuation of Brunner's glands. The observations of Schlemmer, Schwalbe, and Heidenhaim are also mentioned.

It is shown that near the point of union of the stomach and intestine the stomach glands are slightly different to those of the rest of the stomach, the coiled tubes are more branched and convoluted, and the ducts somewhat shorter; further, that the coiled tubes penetrate into or below the muscularis mucosæ; that at about the point of union they break through to a greater degree, that at the commencement of the intestine there are as many in the submucosæ as in the mucous membrane, the muscularis mucosæ splitting up and running among them. At this point the coiled tubes must be called Brunner's glands. Still further down the intestine but few glands are found above the line of the muscularis mucosæ, below it the glands are arranged in separate lobes. Still further down the intestine we find a definite muscularis mucosæ with numerous Lieberkühn's crypts reaching down to it, Brunner's glands consisting of small lobes. Finally, the lobes are smaller and more isolated and then cease.

This continuity of the stomach tubes and Brunner's glands was noticed in man, in the monkey, cat, dog, rabbit, hedgehog, and horse. In the rat this continuity could not be traced.

It was found that at the point of union of the stomach and intestine the epithelium of the surface changes suddenly, so that on one side is seen the regularly arranged cylindrical epithelium of the stomach, and on the other side the granular epithelium of the intestine with goblet cells at intervals. The glands of Lieberkühn begin suddenly at the point of union of the stomach and intestine.

It was, moreover, shown that at the commencement of the intestine, lymphoid follicles are very numerous, so that at times they form a complete ring of half an inch in breadth. This lymphoid tissue, however, varied in amount, the mucosa being sometimes almost free from it, at other times composed in a great measure of this tissue; the latter condition was found to be the case in dogs which were kept on a low diet. The author wishes to lay particular stress on these facts, as he concludes that this excess may, in itself, constitute a pathological condition, and may be connected with some of those pathological changes so frequently met with in this part of the alimentary canal.

On a New Genus *and* Species *of* Zoanthina malacodermata (Panceria spongiosa, sp. n.). By Angelo Andres, Ph.D. (With Plate XVI.)

This new kind of polyp was found in Port Natal, like the allied species *Xanthus viridis*, Kr., and *Pales Cliftonii*, Gr. It has a cylindrical shape, and is four centim. in length and six millim. in diameter (Pl. XVI, fig. 1).

The basis is not muscular, but permanently fixed to the ground, and often spreads out to produce the buds, from which the "blastozoïtes"[1] arise; after the complete development of these the extended portion or cœnenchyma disappears, and the blastozoïtes remain isolated. The surface of the body is completely naked, with shallow transverse wrinkles (Pales). The tentacles (fig. 2) are disposed in two concentric rows; they are alternate to each other, alike, short, simple, conical; their total number is forty-two, half on each row, and, perhaps, originated after the series 6, 12, 24.[2] I have not been able to find either the *bourses marginales* or the *ampulles integumentaires* of Hollard.[3]

Splitting the animal longitudinally, we find a short, conico-cylindrical stomach (fig. 2, *s*), the surface of which is wrinkled in very numerous folds;[4] they are longitudinal, parallel, and divided into five or six superposed rows by transverse annular furrows. In the superior portion, however, no folds are present, so that you may almost infer the morphological division into pharyngeal and gastric region, as Quatrefages did in the Edwardsia.[5] The mesenteric septa are, of course, equal in number to the tentacles; they do not present that pore which in the Actinozoa is considered homologous to the circular canal of Hydroid-medusæ.[6] Not every one bears a filament, but only a few; perhaps twelve on an average. The superior or straight portion of the filaments (fig. 2, *b*) is regular, while the inferior or convoluted (fig. 2, *f*) is more

[1] Lacaze-Duthiers, "Mém. sur les Antipathaires" ('Ann. sc. nat.,' 5, ii).

[2] Hollard, "Monographie anat. du g. Actinia" ('Ann. sc. nat.,' 3, xv). Hollard, 'Études sur l'organisation des Actinies,' 1848. Haime et Milne-Edward, "Sur les Polypiers," &c. ('Ann. sc. nat.,' 3, ix). Lacaze-Duthiers, 'Comptes Rendus,' 1873, &c. C. Semper, 'Zeitschr. d. wiss. Zoologie,' xxii.

[3] Loc. cit.

[4] Conf. Agassiz, 'Contribut. nat. hist. United States.' 'Gosse, 'Actinologia Britannica.'

[5] Quatrefages, "Mém. sur les Edwarsies" ('Ann. sc. nat.,' 2, xviii).

[6] Allmann, "Homolog. Relations of Cœlent." ('Trans. R. S. of Edinburgh,' xxvi).

or less developed in the various septa of the same individual. Hanging in pairs upon the superior portion of every filament are the well-developed, transversely furrowed "branchia-like organs,"[1] or "liver-organ."[2]

Towards the base of the animal the mesenteries run together (fig. 2, *m*) and form an anastomosing, spongy tissue. As the behaviour of the mesenteric folds is, perhaps, the most striking character of the polyp, I add drawings of six transverse sections. Near the tentacles in the pharyngeal region every septum is attached to the wall of the alimentary tube (fig. 3); but in the proper gastric region only a few preserve their attachment (fig. 4).[3] In the so-called branchial region the difference in size persists; the largest septa bear the filaments and the branchiæ, so that their sections appear arrow-shaped; all the septa enlarge at their base and show a tendency to ramification (fig. 5). In correspondence to the convoluted filaments this tendency increases, and some of the branches anastomose together (fig. 6). Farther down the anastomoses become very frequent, till the lumen disappears and a spongy, trabecular tissue alone remains (fig. 8). Moreover, this spongy character extends into the cœnenchyma (see above), so that the buds or zooids are in relation with the body of the mother through a real system of enteric canals, and thus there is in this polyp a point of connection (an analogy, if not a homology) between Zoantharia, Alcyonaria, and Antipatharia.

The histological structure of this polyp is closely similar to that of the other Zoanthinæ.[4] There is a cuticle, a subcuticle, a cellular layer, a layer of connective tissue, a muscular layer, and a mucous layer.

The cuticle is an exceedingly thin, structureless membrane (fig. 9, *a*).

The subcuticle (fig. 9, *b*) is also thin, 0·020 mm., and homogeneous.

Kölliker thinks that this layer has in the Zoanthinæ no individuated importance, and that it apparently belongs to the cuticula.[5] In this polyp, however, it is quite distinct from the cuticle; and, to speak accurately, neither this nor that layer should be called either subcuticula or cuticula;

[1] Dana, "Zoophytes" ('United States Exploring Expedition 1838-42').

[2] Lesueur, "Observations," &c. ('Journ. Acad. Nat. Sc. Philadelphia,' i, 1817).

[3] Conf. Dana, loc. cit., plate 30, fig. 3 *d*, how different.

[4] See Kölliker, 'Die Bindesubstanz der Cœlenteraten.'

[5] Kölliker, loc. cit.

the subcuticle is in this polyp undoubtedly only a continuation of the mesodermic connective tissue, while the cuticle may be considered simply as a differentiation or hardening of its external surface.

The cellular layer (fig. 9 *c*) or ectoderm has its elements gathered together in conspicuous groups of thirty to fifty cells each. These groups are entirely surrounded by the connective tissue, which on the surface towards the cells differentiates a peculiar membrane, like the cuticula of the external surface. The elements are granulations and cells. The former are various in size, and perhaps of pigmentary nature. The latter present three forms, which seem to be only three different stages of a single, identical element, viz. A (fig. 10, *a*), round, apparently isolated cells, with highly refracting nucleus and membrane; B (fig. 10, *b*), similar cells, with a prolongation towards the inner side of the group; C (fig. 10, *c*), nematocysts of ellipsoidal shape, perpendicular to the external surface of the animal, containing a spirally wound filament; they are like the nematocysts of the seventh kind of Haime,[1] or of the fourth of Möbins.[2] The similarity of these groups of elements scattered on the whole surface of the body with the heaps of "Körner, Zapfen, Kugeln," described by Rötheken in the *bourses marginales* as eyes,[3] is very striking; and this may, perhaps, add a new argument against his hypothesis to those already urged by Ludwig.[4]

The connective tissue (fig. 9, *d*) is gelatinous (Kölliker), and presents cells, canals, and fibres.

Of the cells (*a*) some are very distinct masses of protoplasm, with a clear nucleus and nucleolus (fig. 11); (*b*) some are only isolated nuclei with one or two nucleoli, and with more or less slight traces of protoplasm (fig. 12); (*c*) some appear as irregular, finely granular bodies, with crystalline spicules of carbonate of lime, and usually adherent to a fibre (fig. 13); (*d*) some present only a relatively large mass of the same salt and no trace of protoplasm, or only a very trifling one (fig. 14). All these crystals are not so peculiarly shaped as in other Zoanthinæ;[5] still they are homologous with them and with the sclerites of Antipatha-

[1] J. Haime, "Mém. sur le Cérianthe" ('Ann. sc. nat.,' 4, i).
[2] K. Möbins, "Bau und Entwick. der Nesselkapseln" ('Abh. nat. Vereins Hamburg,' v).
[3] Schneider und Rötheken, 'S. B. oberhess. Ges.,' 1871.
[4] Hubert Ludwig, 'Nachrichten d. k. Ges. d. Wiss. Universität Göttingen,' 1875, No. 18.
[5] Kölliker, loc. cit.

ridæ.[1] (*e*) Some show an irregular outline, occasionally a nucleus, and always intercommunicating prolongations (fig. 15). Thus we have a system of canals (fig. 16) excavated through the whole internal moiety of the mesoderm, the mesentery, as well as the body wall, and which are continuous from the parent to the buds; in the spongy region the canals become larger and larger, and get a mucous layer; the whole system communicates through very small openings with the gastro-mesenteric cavity.[2]

Here I again call attention to the close relation of this polyp with Antipatharia and Alcyonaria. Though this touches very near the two important questions of phlebenterism and of the origin of the cœlome, their discussion is not my present task.

The fibres are of three kinds—(*a*) thick, highly refracting fibres, which are sometimes single (fig. 17), sometimes in bundles (fig. 17), and in this case they have a transverse, circular arrangement; (*b*) thin, almost invisible fibres, which, like the former, may be single or form bundles; in one case they are straight or wavy, simple or bifid (fig. 18), in the other always simple (fig. 18); (*c*) the third kind is of pseudo-fibres, viz. of weak, refracting, convoluted forms, which occur in the median portion of the mesoderm (fig. 19).

The muscular layer (fig. 9, *e*) is well developed and presents spindle-shaped mono- or binucleated elements (fig. 20); it is more or less conspicuous, everywhere interposed between connective tissue and endoderm.

The mucous layer (fig. 9, *f*), or endoderm, consists of cells very irregularly heaped together. These cells are loosely connected, and therefore preserve their round shape; their nuclei, and often their nucleoli too, are strongly refracting; nematocysts occur only on the mesenteric filaments; ciliated cells I did not see.

In the lower portion of the body fundamental gelatinous substance and calcareous deposits predominate. Above, on the contrary, the sclerites almost disappear, and the gelatinous substance becomes thickly crossed by muscular and connective fibres of every kind. In the tentacles the ectoderm cells are no longer sunk in groups into the mesoderm, but form a uniform external layer, preserving, however, the three forms already described; the mesoderm is reduced, but the relative quantity of muscular fibres is increased. In the stomach the wall protrudes towards the cavity with appen-

[1] Lacaze-Duthiers, loc. cit.

[2] Conf. Kölliker, 'Actes soc. Helv. sc. nat.,' Génève, 1865.

dices, dendritic in form, not brush-like; at the pyloric ridge there is a distinct muscular sphincter. The branchia-like organs are, histologically, mere outgrowths of the mesenteric folds, as these are of the body-wall. I did not see the canals, which, according to Dana, exist on every transverse stripe. The filaments present no lumen;[1] they have a very thick layer of round cells and of nematocysts; the latter have a regular radiating arrangement, and seem quite similar to each other and to those of the body-wall and tentacles. The three specimens I have examined contained neither ova nor spermatozoa.

From all these characters it appears clearly that this polyp belongs to the group of the *Zoanthina malacodermata*, and therefore is akin to the genera *Polythoa*, *Zoanthus*, *Mammillifera*, *Pales*, *Isaura*, *Orinia*. I have only been able to examine specimens of the first four genera,[2] yet have no hesitation in asserting that the subject of the present description is a decidedly new genus, at least so long as the already established allied genera retain that rank.

That the reader may judge, I expose the characters of the whole group—dichotomously, for brevity's sake:

A. Cœnenchyma involving the whole polyp.—*Polythoa*.[3]

B. Cœnenchyma basilar only.

- *a*. Persistent—adult individuals in colonies.
  - *α*. Regular—colonies of numerous individuals.
    - * Expanded, flat.—*Mamillifera*.[4]
    - ** Slender, cylindrical.—*Zoanthus*.[5]
  - *β*. Irregular—colonies of few individuals.—*Pales*.[6]
- *b*. Not persistent—adult individuals isolated.
  - *a′*. Tentacles in two cycles.
    - * Peristome without velum.—*Panceria*.
    - * * Peristome with velum.—*Isaurus*.[7]

[1] Conf. Leuckart, 'Beiträge zur Kentniss der wirbellosen Thiere;' and Della Chiaje, Rapp, Blainville, Cuvier, &c.

[2] I am very much obliged to Prof. Owen and Dr. Günther, who gave me opportunity to observe the specimens of the British Museum.

[3] Dana, loc. cit. Polythoa . . . polypis latere coadunatis; genus with the ancient Mamillifera and Corticifera of Lesueur. Gray s. i. Polythoa . . . . base subcylindrical, creeping (!).

[4] Lesueur, loc. cit. Dechassaing e Michelotti, s. i. Lamouroux ('Exposit. méthodique des genres de l'ordre des polypiers,' Paris, 1821).

[5] Gray, s. i. Dechassaing e Michelotti, s. i.

[6] Gray, 'Proceed. Zool. Soc. London,' 1867; new genus.

[7] Lavigny, "Polypes d'Egypte," Audouin's 'Expl.' Gray, 'Spic. Zool.' Lamouroux, loc. cit.

β′. Tentacles in a single cycle.—*Orinia.*[1]

I propose the generic name of Panceria in compliment to the distinguished Professor Panceri, of the University of Naples. The following are the characters:

Panceria, g. n.—Cœnecium in juventute tantum existens, saxis adnatum, tenue, parvum, expansum. Polypi liberi, erecti; pariete corporis crassa; tentarulis biserialibus; peristomo parvo, veloque carente; lamellis mesentericis inferne lobatis, varioque modo coalescentibus.

Panceria spongiosa, sp. n.—Port Natal. Length, four centim.; diameter, six millim.; tentacles forty-two; peristome smooth.

The specimens examined were placed at my disposal by the generosity of my respected teacher, Professor Leuckart, of Leipsic, who also suggested their investigation.

CONTRIBUTIONS *to the* PHYSIOLOGY *of* VISION *and of the* SENSATION *of* COLOUR. By Professor FRANZ BOLL, Rome. ('Monatsbericht d. k. Akad. d. Wissensch. zu Berlin,' 11th January and 15th February, 1877.)

I.

EXPERIMENTS on the colour of the retina[2] in frogs, and the changes produced in it by white and coloured light, have yielded the following results:

[1] Dechassaing e Michelotti, 'Mem. Acad. Torino,' xix; new genus.

[2] In my first communication 'On the Anatomy and Physiology of the Retina' (this Journal, April, 1877) I mentioned various earlier observations on the red colour of the retinal elements in Invertebrata. But it had escaped me that Leydig, nearly a quarter of a century ago, had also observed the red colour of the retina in frogs and other Amphibia; and that even the satiny lustre of the dying retina of the frog had not escaped him. His observations are to be found in 'Müller's Archiv für Anatomie und Physiologie,' 1853, p. 8; in his 'Lehrbuch der Histologie des Menschen und der Thiere' (Frankfort, 1857, pp. 238 and 250), and in his paper "Das Auge der Gliederthiere" (Tübingen, 1864, p. 23). That these observations have attracted so little attention, and have remained barren so far as the doctrine of vision is concerned, is explained by the fact that, in the first place, Leydig does not recognise the red colour of the retina as a general character of this membrane, but believes that he has described only a peculiarity of certain retinæ, such as are the coloured oil-drops in the retina of other animals; and that, secondly, the relation of the red pigment to the illumination of the retina has altogether escaped him.

1. *Complete Darkness.*

The colour of the retina when it has been kept in absolute darkness is "red" (not purple-red, as I called it in my first paper). I call this colour the ground-colour of the retina or the "vision red." If we observe with the microscope (Hartnack's objective 7, without cover-glass) the mosaic of the layer of rods, the great majority of the rods shows the same "red" colour which characterises the whole retina. Between these red ones there appear isolated rods of a very pale greenish tint. If we follow the paling of the retina with the microscope, we see that as the colour of the red rods becomes fainter, they assume a distinct yellowish red, and finally, nearly quite yellow tint.

2. *White Sunlight.*

The retina, after the prolonged operation of the sun's rays, or of bright diffused daylight, appears quite colourless. Under the microscope all the rods appear equally colourless and transparent.

3. *Coloured Light.*

In order to investigate the influence of coloured light on the retina the frogs were kept in glass boxes of various colours, which were exposed as far as possible to daylight and to the sun. At the time at which these experiments were made (December, 1876), grey clouds and dark days were rare, or any long continued sunshine was equally rare. The days were nearly all of about the brightness of white-cloud light, and consequently the following experiments are to be exclusively regarded as made with light of medium intensity.

1. *Red Light.*

The glass used in these experiments (glass coloured with suboxide of copper) absorbs the outermost red rays as far as B, transmits the red and orange from B to D, and completely absorbs the yellow, green, blue, and violet from D to G.

Macroscopically the ground-colour of the retina appears unchanged. Under the microscope the red rods behave as in the retina kept in the dark, and gradually pale to yellow in quite the same manner; on the other hand, the green rods scattered between the red ones show a much more brilliant colour than the green rods of retina kept in the dark.

2. *Yellow Light.*

The yellow glass absorbs from the outermost red to C, from which point it transmits the red, orange, yellow, and

yellowish-green as far as E, and then absorbs all the remaining green, and the blue and violet to the end of the spectrum.

Macroscopically and microscopically the retina, exposed to yellow light, behaves in the same way as after the operation of red light.

3. *Green Light.*

The green glass absorbs completely the red and orange to D, transmits yellow and green from D to b, absorbs the greater part of the dark green from b to F, and completely the rest of the spectrum from F.

Macroscopically the ground-colour of the retina appears changed to "purple red." Under the microscope the red rods appear of the same colour; as they pale they pass into a beautiful rose tint. The green rods show the same brilliant tint as after the operation of red and yellow light. Their number, compared with that in retinæ kept in the dark and in red and yellow light, appears not inconsiderably increased.

4. *Blue and Violet Light.*

The blue glass absorbs almost completely the red and orange to D, transmits the yellow and yellowish-green rays from D to E, then again absorbs pretty completely the green from E to b, and from that point completely transmits the blue and violet.

Macroscopically the ground-colour of the retina appears changed to a dull "violet." The numerical proportion of red to green rods is the same as after the operation of green light. The latter appear of a peculiar dirty green, and their presence and colour alone cause the dulness of the violet tint of the retina; for under the microscope the majority of the rods appear of a completely clear bluish-red tint, which in paling passes to a distinct light violet.

It is worth notice that all these characteristic changes of colour by the various kinds of light were produced in repeated experiments with extraordinary constancy; so that I was soon able by examining a retina to distinguish with certainty whether it had been exposed to blue, green, or red (or yellow) light. It is indeed this constancy in the results which induces me to publish them now, without waiting for their confirmation by a second series of experiments carried out with truly monochromatic lights. I am on the point of beginning such experiments; in addition I intend also to study the effect of more intense light of different kinds, a medium intensity having been only observed by me hitherto,

and to settle what alterations are produced in the layer of rods by the intensest possible operation of monochromatic light (monochromatic dazzling).

There are obviously still great difficulties in directly utilising the results at present obtained for a theory of vision and sensations of colour. One of the first questions which arises is as to the significance of the green rods. Must we really distinguish in the frog's retina two morphologically and functionally different kinds of rods, the majority being red and the minority green? Or ought we not rather to assume the fundamental identity of all the rods of the retina, and consider the red and green rods only as appearances produced in similar elements by changing physiological conditions? The circumstance that in the retina which has been exposed to white sunlight no difference between the rods is demonstrable, speaks in favour of the latter alternative, and seems to show that there exists only one kind of these elements. The observations above communicated of the increase in number of the green rods by green and blue light might also be brought forward in support of this view. But unfortunately it must be confessed that these latter observations must not yet be viewed as absolutely decided. For it is highly probable, for many reasons, that the relation of green to red rods in each single retina is not constant, but differs in the various regions of the retina, in the centre and the peripheral zones. But if this be the case, it becomes a very doubtful problem to compare two retinæ together as to their relative richness in green rods, and therefore I dare only speak with great reserve as to the actuality of the observations above mentioned on the increase of the green rods in green and blue light.

But so long as the significance of the green rods is not cleared up, so long as we do not even know whether they are found only in Amphibia, or occur also in the higher and highest vertebrates, in mammals and especially in man, it will be very difficult to utilise the above results for a theory of sensations of colour. The first thing to be done is to carry out a similar series of observations to those on frogs, in an animal whose retina approaches man's as far as possible in structure, *i. e.* a monkey. Perhaps we may then make discoveries which stand in some simple relation to the facts settled by subjective observation as to the sensations of colour in the human retina; and it might then be possible to deduce a really true theory based upon this agreement.

At present the following statements may be viewed as confirmed.

Rays of different wave-lengths act upon the retina in different ways. The red colour of the retina is not changed at all by the rays of the greatest wave-length (red and yellow light). A marked alteration of the ground-colour is at once produced by the rays from the middle of the spectrum (green); and the strongest alteration[1] is caused by the rays of the shortest wave-length (blue and violet) from the extreme end of the spectrum. Probably these three categories of colour are identical with the three primary colours postulated by the theory of Young and Helmholtz.

It is not yet possible to found a theory of colour-sensation on these observations, but I may already point out that a great part of the observed facts are in harmony with the following theory:

"That by the action of the various colours objective colour-changes are produced in the layer of rods of the retina (*i. e.* in a part of the nervous system), which are *identical* with the substance of the sensations and subjective ideas to which they give rise."

If it should be possible to carry out this conception really and thoroughly for the theory of colour-sensation, a completely new solution of the primeval question concerning the reality of the substance of our sentient perception would directly arise from it.

II.

I wish to make a few additions to my previous communication.

I. The constant sunny days of the second half of January have enabled me to determine with greater accuracy than before the duration of the time in which the vision-red is destroyed by sunlight and again restored by darkness. If a dozen frogs are simultaneously taken from complete darkness and exposed to the sun in glass vessels, and if a pair of eyes be examined every five minutes, we find that already in the first five minutes a considerable paling of the vision-red has taken place; after ten minutes a weak glimmer of the red colour may still be demonstrated; but this is very rarely to be met with after fifteen minutes; commonly after this time the retina is already completely colourless; finally, after

[1] In the slight alteration produced by the green rays, and the much stronger change effected by the blue and violet rays in the ground colour of the retina, there may perhaps be found an explanation (assuming the identity of these relations in man) of the fact that the majority of colour-blind people cannot distinguish red from green, while red and blue are confused by very few only. This latter (higher) degree of colour-blindness appears, however, always to include the lower stage of red-green blindness.

half-an-hour, no trace of the original colour could ever be found, and the dying retina did not show a yellowish, but a pure white satiny lustre. Exactly the same experiments were simultaneously performed at a window of the laboratory with a northernly aspect, with the result that diffused daylight requires double or triple the time of direct sunlight to decolourise the retina completely. In another series of experiments, finally, a dozen frogs which had been exposed to direct sunlight for more than an hour were returned to absolute darkness and examined in succession. The first traces of returning redness were never found in these frogs before the lapse of one hour, and were very weak for the most part, even after an hour and a half; after two hours a very intense colouring was usually again present.

II. I repeated the experiments on monochromatic dazzling, and must remark that in these experiments I did not yet use truly monochromatic light, but was obliged to employ the same more or less faulty glasses which had served for the first experiments with light of medium intensity. These experiments yielded the following results: 1. The operation of the most intense red and yellow light, even when continued for several hours, allowed the red colour of the retina to be preserved, but with the difference (scarcely noticeable in experiments with light of medium intensity) that it became in red light still more intense and darker, of a "red-brown" or nearly brown tint, while in yellow light it appeared clearer and lighter, nearly "rosy." The ground-colour of the retina lies midway between these two extreme shades of colour. 2. The dazzling by green light after short duration gives the same results as with the same light of medium intensity. If the dazzling be continued longer than two hours, the colour of the retina becomes altered in the same way as by the action of blue light of medium intensity, *i. e.*, it becomes violet. In still longer dazzling this violet becomes paler and paler and at last the retina appears nearly entirely colourless. 3. Dazzling by blue and violet light of short duration gives quite the same results as the same light of medium intensity. If the dazzling be continued for two hours or more, the violet colour of the retina becomes considerably paler and finally the retina becomes quite colourless, as after the action of white light. 4. In these experiments a phenomenon which was also noticed in earlier experiments came out very distinctly: hand in hand with the progressive decolourizing of the retina, there takes place a peculiar alteration in the consistency of the layer of rods and in the retinal pigment. While in eyes that have been kept in

darkness and in red and yellow light, the retina as far as the layer of rods, may be almost always stripped off as a continuous membrane free from retinal pigment (the processes of the pigment cells being retracted from it), this by no means takes place so smoothly in the decolourised retina; the retina commonly tears into several shreds to which larger or smaller quantities of retinal pigment remain inseparably attached.

III. I have not rashly ascribed the various actions of the separate regions of the spectrum to the different wave-lengths of the rays, and have omitted the obvious reference to the stronger chemical action of the short-waved rays, because experiments on the operation of the ultra-violet rays on the colour of the retina have yielded only negative results.

Observations *on the* Muscular Coat *of* Sweat-glands. By Alfred Sangster, M.B. Cantab. (With Plate XVII.)

It has long been known that some of the sweat-glands of the human subject possess a muscular coat. Kölliker in his treatise on Histology says—

"The canals of glands (sweat) have either thick or thin walls. The latter possess a covering of indistinctly fibrous connective tissue, with elongated scattered nuclei which is sharply bounded internally by a delicate membrana propria, and this is lined by a simple double or multiple layer of polygonal cells. The thick-walled sudoriparous glandular canals have in addition to the two coats above described a middle layer of longitudinal smooth muscular fibres whose elements are readily separable." Concerning the ceruminous glands the same author remarks:—"In their intimate structure ceruminous glands are constituted as follows:—The tube of the glandular coil possesses a fibrous coat and an epithelium. The fibrous coat possesses exactly the same characters as that of the larger sudoriparous glands, *i.e.*, it consists of an internal layer of smooth muscular tissue disposed longitudinally and of an external layer of connective tissue with scattered nuclei and occasionally very fine transverse elastic fibres. The epithelium lies probably on a membrana propria, and consists of a simple layer of polygonal cells which contain yellow-brown pigment cells."

Biesiadecki, writing about the sweat-glands in his article on the skin, in 'Stricker's Histology,' observes :—" The gland tube is composed of a sheath lined by enchyma cells. The sheath is a delicate transparent membrane, that when acted on by nitrate of silver exhibits areas in which are oblong nuclei (Czerny). In the larger glands, as in those of the axilla, numerous longitudinal muscle cells lie on the outside of this membrane, giving a striated appearance to the surface of the gland. The gland tube is lined with a single layer of conical or columnar cells."

The following is an extract from the work on Histology and Histochemistry, by Frey and Leukart:—"Among the convoluted glands we have the smaller and larger sudoriparous organs, the ceruminous glands of the ear, and the lobules, occurring in the conjunctiva of the edge of the cornea in mammals. It is seldom that, as in the latter situation, they possess a simple membrana propria. In most the wall is stronger, this membrane being again enclosed within a layer of connective tissue, between which structures muscular elements may be disposed as a middle tunic, *e.g.*, the large sweat-glands of the axilla."

Lastly, Krause in his Histology, recently published, says, in treating of the sweat-glands :—" The canal consists of an apparently structureless membrane to which externally is applied a single or double layer of unstriped muscle-fibre cells, while most externally we find a connective-tissue adventitia."

It will be seen from the above description that investigators are generally agreed in assigning to the muscular coat of the sweat-glands of the human subject a position external to the "membrana propria." Dr. Klein[1] first called my attention to the fact that in the sweat glands of the sheep the muscular coat is situated internal to the membrana propria. It will be shown that this relation of the muscular coat of sweat-glands holds in other animals, and from what can be observed in the ceruminous glands of the external auditory meatus of man that the same condition *obtained* in the human subject.

Fig. 3 represents a transverse and longitudinal section of part of the coiled tube of a sweat-gland, from a case of sheep pox; the specimen was prepared by Dr. Klein. On examining the preparation from which the drawing was made, the degenerated epithelial lining of the gland tubule can be seen at *a*, appearing as a layer of pale rounded, granular,

[1] "Research on Smallpox of Sheep," 'Transactions of the Royal Society,' v. 164, 1874, p. 229.

cells; with well-defined outlines, which come into view momentarily, while focussing with the fine adjustment; other outlines of the same and other cells appearing at a lower level, the epithelium is coated internally with granular débris. External to the epithelium at *b* can be seen darkly stained bodies, in some parts oblong, and obliquely placed to the circumference, in other parts quadrilateral or rounded; these are sections of spindle-shaped cells composing the muscular coat.

These cells being arranged longitudinally on the gland tube and the latter coiling in sharp curves, it is clear that a section which traverses one side of the gland tube in a plane at right angles to the axes of the spindle-shaped muscle-fibres must necessarily traverse the opposite wall in a plane more or less oblique to those axes, and this accounts for the appearance seen in the figure, where on one side of the tubule the cells are obliquely divided and a portion of their length varying with the obliquity of the section comes into view. Here and there, more darkly stained, can be seen the transversely or obliquely cut staff-shaped nuclei peculiar to unstriped muscle cells.

External to the muscular coat may be recognised, at *c*, the membrana propria; it bears the same hyaline, homogeneous, appearance that is peculiar to this structure wherever it occurs. It is stained darker than the muscle-cells, and in places appears to be prolonged between them, as though they were lying partially within its substance. Surrounding the membrana propria, are to be seen the fibre bundles and interfascicular spaces of the connective tissue, in this case widely separated by œdema. In the longitudinal section the same parts may be readily identified, the muscular coat appears very thick, probably a result of pathological change; it shows faint striation and a few longitudinally divided staff-shaped nuclei. The darkly stained membrana propria appears puckered and very distinct.

Fig. 1 represents three transverse sections of sweat-gland tubule from the ear lobe of the pig. The single layer of well-formed epithelial cells is seen lining the tubule at *a*, the outlines of the cells appear more or less cylindrical in this section, their free borders bulging towards the centre of the tubule. The nuclei are round, large, and regularly placed.

The muscular coat is well seen and the transversely divided staff-shaped nuclei are more plainly visible than in the last specimens. The membrana propria, although not so well marked as in the last specimen, can still be recognised as a thin hyaline membrane situated between the transversely

divided muscle cells and the nuclei bounding the fibrous tissue adventitia.

In fig. 2, which represents in transverse section part of the gland tubule forming one of the ceruminous glands of the human auditory meatus, the structures described in the two preceding specimens cannot fail to be recognised. The appearance of the epithelial lining, however, is peculiar. Between the free borders of the cells composing it and their nuclei is a deposit of what appears under the microscope as brown or yellow granular matter, giving the appearance of a definite zone internal to the regularly placed nuclei. The muscular coat is not so well marked as in the last specimen, but with its darkly stained nuclei still forms a distinct layer inside the "membrana propria," in this instance well defined.

In a less marked degree similar conditions, with regard to the position and appearance of the muscular coat, may be seen in the large sweat-glands of the axilla.

To sum up, then: it would seem that in the sweat-glands of some animals, as well as in those of man, possessing a muscular coat, the epithelium, lining the gland, is seated on the muscular coat without the perceptible intervention of any membrane; again, that the muscular coat is situated internal to the membrana propria lying in the inner portion of its substance; *à priori*, it may perhaps be argued against the above, that Histology up till the present time has furnished no parallel where muscular tissue and epithelium are directly in contact. Whilst fully admitting the weight of the objection, I would urge that the microscopic appearances detailed in this paper admit of no other interpretation.

The observations were conducted under the direction of Dr. Klein.

CONTRIBUTIONS *to the* MINUTE ANATOMY *of the* OMENTUM. By Dr. E. KLEIN, F.R.S. (With Plate XVIII).

I PROPOSE to describe in this short memoir (1) certain bud-like structures occurring on the fenestrated portion of the omentum of rat and dog; (2) the way in which the fenestræ are produced in the omentum of rodents and carnivorous animals; and (3) some points referring to the new formation of blood-vessels in the omentum of guinea-pig.

Before proceeding to detail my observations, I wish to say a few words as regards the methods used in this in-

vestigation. The omentum is carefully removed from the freshly killed animal; in the case of mouse, rat, guinea-pig, and rabbit, the omentum, together with stomach, pancreas, and spleen, is removed from the animal under fluid; in the case of dog or cat a portion of the omentum can be simply cut off and placed in the proper fluid. This is in all cases a 2 per cent. solution of bichromate of potash. The omentum is kept in this fluid for from one to two weeks; small portions of it are then washed thoroughly in water, and stained in hæmatoxylin, or better first in carmine and then in hæmatoxylin. I shall have occasion hereafter to point out the advantage of this double staining. The stained preparations are finally mounted in glycerine.

1. Examining carefully the fenestrated portions of the omentum of a full-grown rat, larger or smaller bud-like projections are found on the bundles of connective tissue forming the trabeculæ of the fenestræ. These buds are covered with the same endothelium as that lining the trabeculæ (see figs. i—v); they are not as a rule in connection with the connective-tissue bundles, except in later stages, where the content of the buds becomes itself fibrillar tissue. As regards the size, they vary very much. Those represented in figs. i—v are all relatively small, but there are others twice, thrice, and even more times as large as that represented in fig. iv or fig. v. The smallest buds are those in figs. i and ii; they are either pear-shaped, and by their stalk attached to the trabeculæ, or they are conical with very broad basis, by means of which it rests on the connective-tissue bundle. An interesting form is presented by some of them being of more irregular form and of a plate-like extension, with one or more spindle-shaped thickenings (see fig. iii). In the young stages the buds are composed, besides the covering endothelium, of a substance which is very indistinctly granular, and which stains, somewhat like the connective-tissue bundles, conspicuously in carmine; the endothelium, on the other hand, has a greater affinity to hæmatoxylin, and hence the usefulness of staining the preparation in carmine and in hæmatoxylin. But while the bud-like structures have a greater affinity to carmine than to hæmatoxylin they are not altogether indifferent to the latter; this is especially the case with the larger examples that we find in the more dense part of the fenestrated portion, for these assume a peculiar purple colour which makes them very conspicuous among the rest of the tissue, and under these circumstances are very easily distinguished. Not all buds contain, or rather are composed

of, that indistinctly granular substance, for in some we may distinguish under a high power very delicate fibrils, while in still others the whole mass seems to be composed of a more or less distinctly fibrillar tissue. In the latter case the fibrils have either a concentric arrangement, as in fig. v, or they form a thinner or thicker bundle, much convoluted, and situated parallel to the surface of the corresponding trabeculæ (as in fig. iv), or vertical to it. The fibrillar nature of such a bundle is very well shown if in the course of preparing the specimen the endothelial covering breaks and the bundle of the bud-like structure becomes uncoiled. It may then be ascertained that there exists no difference between this bundle and the ordinary connective-tissue bundles of the trabeculæ. As the contents of the bud-like structures become more distinctly fibrillar we find that it enters also into a closer connection with the subjacent connective tissue. The question presents itself now, How do these bud-like structures develop? The earliest, or what appears to be the earliest, stage is a small prominence due to the presence of one, two, or three, or probably more, slightly flattened cells, the substance and nucleus of which places them in the same category with the endothelial cells of the surface. In the next stage the substance of these cells, except the one covering the prominence, becomes indistinctly granular, the outlines of the cells becoming at the same time indistinct or altogether lost; whereas the nuclei lose their power of staining with hæmatoxylin or carmine; their outline becomes soon indistinct, and finally they are altogether lost. In figs. i, iii, and v very faint outlines of nuclei are still distinguishable.

The description hitherto given applies to the examination of the omentum of rat, but also in that of half-grown dog have I observed similar bud-like structures, only these are less numerous. I should say that those that I have seen, were of the same kind as that represented in fig. v; they showed already fibrillar structures, the fibrils being arranged concentrically, and among them were remnants of one or two nuclei.

So that it appears that bundles of fibrillar connective tissue are being formed in the omentum by the direct conversion of cells. These cells are in all respects similar to endothelial cells. This is in conformity with an almost generally assumed theory; it is, however, not quite in accordance with what Rollett states ('Stricker's Handbook,' chapter on Connective Tissue) as regards the development of the connective-tissue bundles of the fœtal omentum. In my

'Anatomy of the Lymphatic System' (part i, serous membranes) I stated that under pathological conditions bud-like and papillary or villous projections grow out from the surface of the serous membranes (fenestrated as well as non-fenestrated parts), and that the connective tissue forming the matrix of the larger or further advanced papillæ does not seem to be produced by the distinct conversion of the substance of endothelial cells, as stated by Kundrat ('Stricker's Jahrbücher,' 1870), but appears rather as a kind of secretion. This, however, is certainly not correct in the case of the projections of the normal omentum as described above, for here the newly formed connective-tissue bundles are derived directly from the cell-substance, and it is, therefore, not unlikely that the same takes place also under the above-mentioned pathological conditions.

At one time I was not disinclined to derive some of the young buds of the omentum of rat, represented in figs. i and ii, from peculiar large migratory cells, which seem to occur only in the omentum of white rats. They are conspicuous by their large size, their coarse granulations, which staine very deeply in hæmatoxylin, and also, but to a less degree, in carmine, and by their clear round nucleus, which was not, however, stained with the above reagents; and in this respect alone they differ markedly from the other cellular elements of the membrane. These migrants are found in considerable numbers among the cell-accumulations around the large blood-vessels, whence they may be traced into the smaller trabeculæ of the fenestrated portion. At some places these cells are changed into fat-cells.

As I said before, I was at first inclined to assume that some of our buds are derived from these large migrants, especially those figured in i and ii, by assuming that their coarse granulations gradually disappear, and that also their substance undergoes the above-described alterations, but not being able to find intermediary forms I cannot support that assumption.

Before concluding this part of the paper I wish to mention the changes that are observable in the nuclei of the surface endothelium of the fenestrated portion of the omentum of rat, consisting in this :—Amongst the ordinary oblong nuclei of the ordinary endothelial cells (like those represented in figs. i—v) there are seen occasionally oblong or round nuclei [the ordinary nuclei are on the average about 0·0135 by 0·0051 millimètres] considerably larger, even twice as large. They show very often constrictions, as if dividing, or are nearly completely divided into two or even three smaller

nuclei. The presence of two nuclei in one endothelial cell was, however, seldom met with in the omentum of rat.

The presence of smaller or larger groups of germinating endothelial cells occurring in various parts of the normal omentum and pleura of various animals, fully described and figured in the above-mentioned book, need not here be mentioned specially.

2. According to Rollet the fenestræ of the omentum are surrounded by connective-tissue bundles, which return in themselves, and judging from his fig. 3 in his article on connective tissue, one is led to suppose that in the omentum there are no other bundles but such as surround the fenestræ and return in themselves. Ranvier ('Travaux de laboratoire d'Histologie,' 1874, p. 140) questions this statement, and maintains on the contrary that there are no bundles returning in themselves, and that the fenestræ originate by the simple separation of bundles, *i. e.* are merely holes between bundles. Ranvier thinks it probable that the holes are produced by migratory cells penetrating through the membrane.

Examining the omentum of young rabbits and guinea pigs, prepared in the above manner, the origin of the fenestræ becomes easily understood; the examination of the omentum of rats and half-grown dogs gives us also valuable information as regards the arrangement of the connective-tissue bundles in the fenestrated part. There is a considerable part of the omentum of young guinea pigs (three to four weeks old), and still more, of young and even full-grown rabbits, which is of a dense structure, containing only here and there a few small holes. The omentum of guinea pigs (three to four weeks old) is especially valuable in this respect, showing us at once the origin of the holes. In fig. vii I have represented a small portion of such an omentum. As is shown in the figure, the membrane consists of connective-tissue bundles, arranged more or less parallel to each other; on the surface of the membrane are seen the nuclei of the endothelium (the outlines of the endothelial cells becoming of course visible by nitrate of silver). Further, we see a number of well-defined holes, *a*, passing right through the membrane, these holes being of different sizes. And finally, we notice *in* the membrane a number of round spaces (vacuoles) of different sizes—in some parts their number being very considerable; some of them contain a small nucleus, *i. e.* the nucleus of a connective-tissue cell, the substance of which may be made out occasionallly as granular protoplasm situated at and extending from the poles of the

nucleus. On carefully looking over a portion of the omentum it can be ascertained that the last-named spaces are vacuoles which open completely on one of the surfaces. I presume the only interpretation that can be put on these different appearances is this: there appear smaller or larger vacuoles in the substance uniting the connective-tissue bundles, which ultimately open through the endothelial membrane first of one then of the other surface. These vacuoles appear not only at those places between the bundles, where there is situated a connective-tissue corpuscle—in this case the vacuole appears to be lined on one side by the cell,—but also independently of these.

Comparing with the above specimen one that had been stained in the usual manner with nitrate of silver, we perceive that the smallest examples of those holes which penetrate completely through the membrane (*a* in fig. vii) correspond to the interstitial substance of the endothelial cells of the surface; so that the above holes of the omentum are due to a dehiscence of the interfascicular, and also of the corresponding parts of the interstitial substance of the surface endothelium, viz. two substances which, as is well known, are identical in their chemical characters. That, therefore, the theory of Ranvier, viz. that the holes are caused by migratory cells, is to be dismissed need not be specially insisted upon. The absence of migratory cells in many parts where the holes are just being formed—judging from the very small vacuoles found in the membrane—confirms this conclusively. I presume the above vacuolation is due to the presence of fluid in the interfascicular substance, probably liquefaction of part of this substance, and that a similar process in corresponding portions of the interstitial substance of the endothelium leads to the establishment of complete holes.

Turning now to the examination of the omentum of young and half-grown dogs and rats we ascertain the following important appearances:

(*a*) Apart from the large trabeculæ containing large blood-vessels, we find some parts in the fenestrated portion which are of a denser structure; they contain, besides the surface endothelium, a considerable number of connective-tissue bundles, arranged parallel with each other; between these we find the ordinary connective-tissue corpuscles.

(*b*) In some extensive portions, however, the meshes of the fenestrated part are surrounded by thin trabeculæ which are composed of a single connective-tissue bundle, ensheathed

by the surface endothelium. There are no connective-tissue corpuscles within this kind of trabeculæ.

Between *a* and *b* we find all intermediary forms, *i. e.* broader or narrower trabeculæ, according to the larger or smaller number of connective-tissue bundles of which they are composed, and between these lie the corresponding connective-tissue corpuscles. Examining more carefully one of the smaller of these intermediary forms of trabeculæ, *i. e.* one containing a small group of bundles, like the one in fig. vi, we have two important facts.

First, we see at the points where three or more trabeculæ meet, an accumulation of nuclei; examining these places with a moderate power we find that the nuclei are due chiefly to cells situated between the connective-tissue bundles, the nuclei being surrounded by granular protoplasm. (In preparations prepared with bichromate of potash, and then stained as described above, the nuclei belonging to the covering endothelium cannot be easily distinguished except by very careful focussing; staining with silver gives satisfactory information.) A second fact of equally great importance is the presence of vacuoles between the bundles of connective tissue. In the drawing under consideration we see that these vacuoles are between the bundles, and in a more or less distinct linear arrangement. It is easy to understand how by the increase in size of these vacuoles a group of meshes is established, or how by the coalescence of two or three vacuole meshes of considerable size are formed.

As in the case of the guinea pig (see above), so also here we find that in some vacuoles are contained nucleated cells. The examination of a number of places like the one represented in fig. vi leads one to suppose that the accumulation of nucleated cells at the junction of trabeculæ represents the stock from which cells extend by active growth between the bundles, and are destined to become the covering endothelial cells of the latter when this part becomes fenestrated.

From the preceding description it appears that the meshes or holes in the omentum are caused by the separation of the bundles from each other; that is to say, they appear between the bundles (the connective-tissue corpuscles situated between these representing the endothelial cells after the fenestration of the corresponding parts), and that therefore Ranvier is right against Rollett, according to whom (as mentioned above) each hole is surrounded by a bundle returning in itself. Although the statement of Rollett is not correct in the above form, still it may be rendered correct by slightly

modifying it in saying, that there are holes which appear at first sight to be surrounded by returning bundles, but which on careful examination are seen to surround only about half or two thirds of the circumference of the hole.

Staining a portion of omentum of an adult rat in carmine (after having been kept a few days in the bichromate of potash solution) and spreading it out with a rather firm hand on an object glass and mounting and examining it under the microscope, the arrangement of the connective-tissue bundles is very evident. In some parts we see trabeculæ, which are composd of three bundles; a middle one, and on each side of this a thin one bordering on a hole and apparently surrounding it. But, on looking more attentively, it is found that it does not return in itself, but is a branch of a larger bundle, and, having surrounded the hole for the greater part of its circumference, joins again another bundle. This condition is quite compatible with the formation of the holes by vacuolation.

3. In my 'Anatomy of the Lymphatics,' I, 1873, p. 11, and following, I have minutely described the occurrence of opaque patches of different sizes (more or less covered with germinating endothelium) the matrix of which contains a great abundance of cells. The youngest and smallest of these milky patches have no blood-vessels, whereas the larger ones are provided with a special system of capillary vessels. I have also stated then (l. c., pp. 58, 59, and 60) that in the omentum of most animals a constant development of new vessels takes place in these patches of the omentum, either in connection with already formed vessels by solid protoplasmic processes which become gradually hollowed out (as described by Stricker and Arnold) or independent of already formed vessels by vacuolation of some of the connective-tissue corpuscles of the matrix of the above-named patches (the vacuolation of cells is, as I have pointed out in the second section of that work, of great importance also in pathological respect).

Ranvier, a year later, in a paper published in 1874[1] (l. c., p. 148), drew attention to the opaque patches in the omentum of rabbit and he gave to them a special name, "*tâches laiteuses.*" Those cells of the matrix of these patches of which blood-vessels are developed Ranvier calls "cellule vasoformatives."[2]

[1] Both the reporter in the 'Centralblatt f. Med. Wissensch.,' and the reporter on "Histology," in Virchow's 'Jahrbücher,' while reviewing Ranvier's paper, are quite unaware of my description of the above patches and their importance for the development of blood-vessels.

[2] It seems to be necessary to have always in readiness a few new names, otherwise your descriptions will be left unnoticed.

Ranvier's description of the mode of the formation of blood-vessels in these patches varies somewhat from that described by myself. After a new investigation of the development of blood-vessels in similar patches of the omentum of very young guinea pigs, I have come to the conclusion that the mode of development of blood-vessels in the young animal corresponds to that described by me of those in the rabbit and not to that maintained by Ranvier. If a preparation be prepared in the above manner (2 per cent. bichrom. of potash for eight to ten days, washing in water and then staining in hæmatoxylin or carmine and hæmatoxylin) from the omentum of a young guinea-pig (not older than three or four weeks) and the vicinity of large vessels be examined, numerous places may be sought out in which a development of new blood-capillaries can be easily discovered.

Fig. 8 accompanying this paper is taken from such a part. In this figure there are two capillary vessels which are still in a young condition; they still show the cells by whose vacuolation and fusion the vessel has been formed. In close vicinity to the vessels we find very numerous cells, the greater number of which are vacuolated in various ways, as is shown in the figure. These vacuolated cells have a more or less distinct linear arrangement, and we have only to imagine that those parts by which they are in contact become absorbed or disappear, to obtain a portion of a capillary vessel. Although the number of vacuolated cells is smaller in most patches where the development of blood-vessels has begun, than that represented in figure 8, still it is so large in my specimens that their importance for the development of blood-vessels cannot be overlooked. Besides, the condition and aspect of the young capillaries like those represented in fig. 8 strongly support the view just mentioned.

To say that the vacuolated cells and the above condition of the young capillaries is due to the influence of the reagent used (2 per cent. solution of bichromate of potash), would be against all our experience of the action of that fluid. From the foregoing we see that vacuolation is important for the origin of the holes at the fenestrated omentum in general and also for the development of capillary vessels in the patches and nodules, in the omentum of the young guinea pig; in the former case the vacuolation takes place in the interstitial substance of the connective-tissue stroma, in the latter case in the cells of the matrix; and by fusion of the vacuolated cells capillary vessels are formed.

The omentum of the above case has not been fenestrated yet; it contained only indications of it in the form of a few

holes, as described in paragraph 2. If the omentum be already fenestrated, the vacuolated cells become very few, although development of capillary vessels is still going on. I refer to the examination of the omentum of a guinea pig about six weeks old, which omentum is abundantly fenestrated, almost like that of an adult animal. Although I do not see here any such conspicuous appearances of vacuolated cells near the capillary blood-vessels, as in the former case, still there are capillary vessels to be met with in small patches, the wall of which still shows traces of its mode of development, viz. by fusion of vacuolated cells, like the capillaries in fig. 8. There are, however, other appearances which are in perfect harmony with the vacuolation theory. Thus I have before me a small patch with a network of capillaries, from the wall of one of which solid protoplasmic threads of great fineness extend, running in a slightly curved manner over a distance of one to three millimètres, and ending in the wall of a capillary vessel of a distant patch. The thread in question contains seven spindle-shaped swellings, which contain either a single nucleus or a small number of nuclei (two, three, or four); in the latter case the fusiform swelling shows more or less advanced vacuolation. There can be no doubt that this thread will finally become converted into a blood-vessel, for other such threads may be found in different stages of development. Thus is explained the presence of solitary capillary vessels found in the omentum, and extending from one vascular cell-patch to another, sometimes for a conspicuous distance—a distance occasionally to be measured by the inch-measure. Besides the above nucleated protoplasmic vaso-formative threads there are other fine nucleated protoplasmic threads, which appear to lose themselves in the connective tissue of the matrix; they are at some places of great length (1—3 mm.), and contain a nucleus at several places at regular intervals; they are probably nerves. I believe I have seen them in connection, or what appears to be a connection, with the vaso-formative threads.

On the PROTRUSION *of* PROTOPLASMIC FILAMENTS *from the* GLANDULAR HAIRS *on the* LEAVES *of the* COMMON TEASEL (*Dipsacus sylvestris*). By FRANCIS DARWIN, M.B. (With Plate XIX.)

THE connate leaves of the common teasel (*Dipsacus sylvestris*) form, as is well known, cup-like receptacles surrounding the stem of the plant. In the rain-water accumulating in these cups numerous insects are drowned, and their dead bodies convert the water in which they lie into a strongly animalised fluid.

In the autumn of 1875 I examined the leaves of the teasel, in the expectation of finding the same evidence of the absorption of the products of decay as may be observed in the remarkable trichomes lining the bladders of Utricularia.[1] The glandular hairs or trichomes on the leaves of the teasel proved, however, to be too much shrivelled for the experiment, although the leaves were not themselves withered. In the summer of 1876 I recommenced the investigation by examining transverse sections of teasel leaves mounted in dilute ammoniacal solutions such as those which are absorbed by the glands of Drosera, Pinguicula, &c., and by the trichomes of Utricularia, and which my father has shown to give rise to the remarkable phenomena of "aggregation."

While examining the transverse section of a teasel leaf (under Hartnack's objective No. 8) I observed a translucent, somewhat highly refracting mass seated on the summit of one of the glands. I imagined it to be resin, excreted in the form of a filamentous mass. I was therefore astonished to observe a few moments later that its shape had distinctly altered. On finding similar filaments on several neighbouring glands I became convinced that the subject was well worth investigation.

The first idea that presented itself was that the filaments were protoplasmic organs specially adapted for the absorption of the fluid containing decayed animal matter collected in the teasel cups. This theory was overthrown by the following facts. The teasel is a biennial, and during its first year's growth consists of a mere rosette of radical leaves, the cup-bearing stem being formed during the second year. But the supposed pseudopodia are found not only on the connate leaves of the second year's growth but on the radical ones produced during the first season. They are also found in *Dipsacus pilosus,* whose leaves are not sufficiently connate to retain water, and which can therefore capture no insects. These facts prove conclusively that, whether

[1] 'Insectivorous Plants,' p. 418.

or not the glands have anything to do with the absorption of the putrescent fluid in the cups of *D. sylvestris*, some other function must also be performed by them in the economy of the plant. Another idea which occurred to me was that the filaments might be low organisms of the nature of a Myxomycetes, living parasitically on the summits of the glands. The reasons for discarding this view will be fully given in the sequel.

The trichomes on the connate leaves of the second year's growth all have the shape of glandular hairs (except a double row of simple multicellular hairs on the midrib); the seedlings possess in addition numerous long hairs or prickles, the chief portion of which consists of a single large conical cell, sometimes ·85 millimeter in length, and ·09 millimeter in breadth at the base. The *glandular* trichomes are of two kinds, exemplified by figs. 1 and 13. The trichomes of the fig. 1 type are of no further interest, as they do not produce motile filaments. The other variety (fig. 13 and the other drawings) consist of a pear-shaped multicellular head, about ·05 millimeter in length, and a unicellular cylindrical stalk a little over ·03 millimeter in length, supported on a cushion-like cell projecting to a variable extent above the level of the epidermis; the whole trichome is about $\frac{1}{10}$th millimeter ($\frac{1}{250}$th of an inch) in height. In the glands on the second year's leaves the cells forming the pear-shaped head usually contain a few bright spheres of a resinous substance: the latter may be removed by alcohol, and then the nuclei of the cells become clearly visible. These large drops of resin are often absent, especially from the glands of the seedling leaves; in this case the cells contain merely granular and cloudy protoplasm. The drops of resin are, however, sometimes to be found in the seedling's leaf-glands, as shown in fig. 13. Both the trichomes of the fig. 1 type, and also those which produce filaments, occasionally contain a good deal of starch.

The stalk-cell exhibits a simple network of streaming protoplasm and a large nucleus. I have once or twice observed streams of protoplasm in the transparent cells forming the pear-shaped head of very young glands. The glands are often capped by accumulations of resinous secretion, and this is more frequently the case with the second-year leaves than with the seedlings. These secreted masses agree with the bright spheres found within the cells in exhibiting the following reactions, which show them both to be of a resinous nature. They are soluble in ether or alcohol, are coloured pink by tincture of alkanet; they are not blackened by osmic acid, as would be the case with a fatty substance. The crusts on the outside of the glands, contrary to what might be expected, are stained yellow with iodine. It appears, therefore, that the resinous secretion is

formed in drops in a vacuolated protoplasm in the gland-cells of the trichomes, and, passing through the cell-walls, collects on the external surface of the gland. In his paper on glandular trichomes Hanstein[1] describes a method of secretion in which the product collects in a blister-like cavity beneath the cuticle, which bursts and allows it to escape. On dissolving the resinous crusts from the teasel glands I have occasionally seen a similar bladder of cuticle subsiding or bursting. Martinet[2] describes a similar process, and considers it pathological and of only occasional occurrence. I imagine that in the case of the teasel the essential act of secretion, *i.e.* the elimination of a resinous product from the cells in which it is formed, is a normal process; but possibly the method of elimination may vary, so that a bladder may or may not be formed. The resinous matter is secreted only by the trichomes of the types shown in figs. 2, 3, 4, 13, &c., that is to say, only by those from which the motile filaments are produced.

The motile filaments.—Various forms assumed by these remarkable bodies are shown in figs. 2, 3, 6, 7, 8, 9, and 16.

The typical form consists of a simple thread-like body slightly clubbed at its free end. The filament shown in fig. 3 was nearly ·1 millimeter in length, and about ·0012 millimeter in breadth at the thickest place. The dimensions vary extremely; for instance, the thickness may be reduced to that of the very delicate filament seen in fig. 6, whose length cannot be estimated because of the complicated tangle in which it is arranged. Another and far more elaborate knot of filaments measured ·2 millimeter in length; if it was composed of a single filament, which is quite possible, the latter would certainly have been 2 millimeters in length when uncoiled. Even the comparatively thick filament in fig. 2 measures ·4 millimeter in length. These entanglements are of common occurrence, and usually consist of a labyrinth of sweeping curves lying close up to the gland. Fig. 6 was selected from the curious angular disposition of the coils. Again, the thickness may be larger when compared with the length, as in the smaller masses in figs. 2 and 3; and thick, partly dumb-bell shaped masses may be combined so as to produce a branched filament, as in fig. 16. In fig. 4 an almost spherical filament[3] is seen. In fig. 16, again, rather thick filaments are seen, one of which forms a loop by having its distal end attached or closely applied to the summit of the gland. The formation of loops is an extremely common phenomenon; they do not seem to be

[1] 'Bot. Zeitung,' 1868.
[2] 'Annales des Sc. Nat.,' 1865.
[3] The word filament is used to express any motile mass, of whatever shape it may be, arising from a gland.

formed by the distal end of the filament becoming attached to the gland, but I believe that they *arise* as loops, or that two filaments unite and form a loop immediately after emerging from the gland. Variously beaded forms are shown in fig. 9, and a crowd of irregularly shaped masses in fig. 7.

The filaments are with the very rarest exceptions attached to the summit of the gland; and when the actual place of attachment can be made out, it is found to be at the point where the radiating cells meet in the centre of the dome-like surface of the gland, or at least on the junction line between at least two cells. The substance of which the filaments are composed is translucent, highly refracting, and quite free from granules. The filaments are in constant tremulous Brownian movement, showing that they are of a gelatinous consistence. I hope to prove that they consist in part at least of protoplasm, but I have not succeeded in showing the presence of albuminoids by any of the usual micro-chemical tests. Neither the rose-red colour with syrup and sulphuric acid, nor the xanthoprotein test with nitric acid and ammonia succeeded properly, though a distinct faint tinge was produced by the latter means. The filaments, however, assume a bright yellow colour with iodine, but I presume that no great weight ought to be attached to this reaction. The filaments are not stained by ordinary colouring fluids, such as logwood, anilin, &c. It will be shown that the substance of which they are composed consists in large measure of a resinous substance mingled in some way with the protoplasm, and I presume that it is this circumstance which interferes with the above reactions.

Protrusion of the motile filaments from inside the glandular trichomes.—I have hitherto spoken of the filaments as merely attached to the surface of the glands, but they are in fact protruded from the inside. There can be no doubt of this, for glands may be observed whose dome-like summits are quite naked and bare, but which may be seen after a few moments to be surmounted by a minute projection which grows up into a normal filament by visible increments in length. I cannot positively state by what means the filaments traverse the external cell-walls. It might be supposed that apertures would be found to allow of their transmission. By stripping off the epidermis a bird's-eye view of the summits of the trichomes is obtained, and if any apertures exist they would be probably visible in this way, but no such appearance can be seen. But the tops of the trichomes ought to be cut off by sections parallel to the surface of the leaf, to decide the point with certainty. It is extremely unlikely that apertures should exist, and the protrusion of the filaments can be explained without assuming their exist-

ence, for semifluid secretions undoubtedly pass through cell-walls, and there is no difficulty in believing that gelatinous protoplasm may do the same.[1] The migration of blood corpuscles occurs where no special apertures exist for their transmission.

The protrusion of filaments was first observed in sections of leaves mounted in a dilute solution of carbonate of ammonia; but the presence of this salt is not necessary, as the filaments issue forth vigorously in distilled water. A very slight film of moisture on the surface of gland is sufficient to allow of protrusion taking place. For I have seen filaments protruded when looking vertically down on to the surface of a damp leaf. Whether they are protruded from a perfectly dry leaf I cannot ascertain.

Movements of the filaments.—The most remarkable movement exhibited by the filaments is a violent contraction. This is especially well seen by irrigating a preparation with dilute acetic acid (2 or 3 %). In figs. 3 and 4 a filament is shown before and after treatment with dilute acetic acid. The contraction is often so energetic that the whip-like filament seems suddenly to be replaced by a ball seated on the summit of the gland. After the act of contraction the substance of the filament is denser and more highly refracting. When the contraction is not so violent its course may be watched. It usually begins at the free end of the filament; a ball appears at the distal extremity and increases in size as it rapidly approaches the gland, being connected with it by the remaining uncontracted portion of the filament, which of course quickly diminishes in length. I have also seen the contraction begin at the proximal or attached end of the filament; a ball forms on the surface of the gland, and increases as the extended portion diminishes. These violent alterations in form are frequently preceded by a most beautiful phenomenon which I have called "moniliform" contraction. This appearance is shown in fig. 9; here the filament retained this form for some time, and was in fact in a chronic state of contraction. The "acute" moniliform contraction presents the same appearance, but lasts only a few seconds. Sometimes the moniliform contraction invades the whole filaments so rapidly that it seems simultaneous; in other cases it is distinctly seen spreading along the filament. When the constrictions between the "beads" are not especially deep, the beads and the spaces between them appear alternately light and dark as the focus is changed. I have occasionally seen a momentary appearance of alternate light and dark bars throughout the whole length of the filament, instantly followed by violent

[1] See a paper by Max Cornu, "Sur le cheminement du plasma au travers des membranes vivantes non perforées," 'Comptes rendus,' Jan. 15th, 1877.

contraction. This appearance may be due to a moniliform contraction in which the outlines of the beads and constrictions are not perceptible, or may possibly be due to the contraction occurring at a series of equidistant points, the refractive index being raised at each point in consequence of the increased density of the tissue. It should be added that contraction frequently occurs without being preceded by moniliform appearance.

I have hitherto spoken as if after the completion of the act of contraction the filament were always found massed into a spherical body on the gland from which it took its origin. This is normally the case, but in rare instances a long filament becomes entangled with a neighbouring gland, and when contraction takes place the filament snaps in two, one portion remaining attached to its own gland and the remainder actually contracting on to the foreign surface by which it had been entangled. It must be noted that filaments frequently break loose from their attachment, and while in this free state are capable of contracting and exhibit other signs of vitality. These two observations are important because they throw some light on the nature of the act which I have called contraction. A friend suggested that possibly the filament may not undergo a true contraction, but that its movements may be governed by changes occurring within the gland, so that the filament itself is merely passively acted on by these internal agencies. But it is evident that this cannot be the case, because freely floating filaments are capable of contracting, and because the distal portion of a filament exhibits the same power independently of the proximal portion.

Causes inducing contraction.—In the present section I shall examine only those causes which produce the violent changes of form which I have hitherto called "contraction." Under certain conditions the filaments assume an amœboid state in which gradual alterations in shape spontaneously occur; it is obvious that these movements may quite as justly be supposed to be due to contractility; but these movements are excluded from the present discussion, and will be considered in the sequel.

Acetic acid.—The contraction caused by this reagent has already been described. The filaments are very sensitive to its action, and contract violently when exposed to a solution of 1 per cent. Also distinctly with a much weaker solution, ·2 per cent.; but on the other hand some filaments were found in a half expanded state after three hours' immersion in ·4 per cent. acetic acid.

After the protoplasm of the filament has been killed by the action of acetic acid, a remarkable change occurs. The contracted mass swells and becomes more transparent, and produces a pile of polyhedral vesicles, whose shape is determined by mutual

pressure, so that it somewhat resembles in appearance a heap of soap-bubbles, as shown in fig. 5. I may remind the reader that when a colourless blood-corpuscle dies it swells up into a transparent sphere, owing to the imbibition of water,[1] and I believe that the formation of the soap-bubble mass is due to the protoplasm of the filament imbibing water at a number of different points.[2] This soap-bubble appearance is not specially connected with death by acetic acid; it appears to be a result of any kind of death, and may be seen where the filament has been killed by other reagents (such as $\frac{1}{2}$ per cent. solution of chloride of gold) or by heat. On the other hand it is not the invariable accompaniment of any kind of death, simple balloon-like masses being often produced by the swelling of the protoplasm in a single mass.

Sulphuric acid.—By irrigating with 2 per cent. solution of sulphuric acid contraction was several times produced. Weaker solutions were not tried.

Hydrochloric acid.—As my father found this acid not poisonous to Drosera, a dilute solution (2 per cent.) was tried with the teasel. Contrary to my expectations, it proved poisonous, always causing contraction and death of the filament.

Boracic acid.—This acid is not poisonous in a weak solution. Several long and delicate filaments were found protruded after being immersed all night in ·2 per cent. solution, and they contracted at once with dilute acetic acid. In this case the teasel agrees with Drosera, as boracic acid is not poisonous to the latter.[3]

Citric acid.—This acid is not poisonous to Drosera,[4] and is so to the teasel, but I cannot speak decisively as to how poisonous it is. A solution of 1 per cent. rapidly causes contraction. A solution of ·5 per cent. usually produces contraction after a time, and also kills the glands. But two filaments withstood a solution of this strength for between seventeen and eighteen hours; two others were not made to contract by five hours' immersion in the same solution.

Osmic acid.—The action of this highly poisonous acid has surprised me much. As is well known, its usual effect on protoplasm is to kill it instantaneously without altering its appearance. This is not the case with the filaments of the teasel, at least with weak solutions of the acid, which act like acetic or sulphuric acids, but not so vigorously, and sometimes not completely. I record in my notes that on irrigating with $\frac{1}{4}$ per cent. solution of osmic acid a whip-like filament "contracted into a barred and knobbed cylinder." I then irrigated with water, and

[1] 'Handbook for the Physiological Laboratory,' p. 12.
[2] Perhaps this may be connected with the filament's power of contracting at a number of equidistant points.
[3] 'Insectivorous Plants,' p. 191. [4] Ditto, p. 194.

the filament subsequently showed itself to be still alive by changing its form and contracting with dilute acetic acid. This filament was therefore made to partially contract without being killed, instead of the normal effect of the poison being produced, viz. death without contraction. After numerous trials I conclude that irrigation with acid of this strength either causes complete or almost complete contraction, or else no effect is produced and the filament withstands the poison. This is a remarkable fact, as the *glands* are soon killed and blackened by ¼ per cent. osmic acid; it shows that the *filaments*, when once protruded, are independent of the life of the gland. With 1 per cent. osmic acid I succeeded in obtaining a different result; a filament began to contract and then died in a partially expanded state, and afterwards resisted the action of strong acetic acid. In another instance the filament was half poisoned by osmic acid and only contracted after prolonged irrigation with 20 per cent. acetic acid. In another case a filament contracted partially with osmic acid and then withstood 20 per cent. acetic acid, showing that it was killed by the osmic acid.

Various salts.—Carbonate of ammonia in dilute solutions, viz.: ½ per cent., causes moniliform contraction; the filament becomes partially concentrated into a ball, and then recovers, and extends itself again. The most interesting points in connection with this salt have no bearing on the simple contraction of the filaments, and will be discussed later. The same remark applies to the carbonates of potassium and sodium, both of which cause contraction in ⅓ per cent. solutions.

Chloride of gold in ½ per cent. solution causes rather languid contraction. But the filaments are killed by it, and become transformed into soap-bubble masses.

Nitrate of silver in ¼ per cent. solution has the same effect, viz. contraction and death, followed by the production of a soap-bubble mass.

Iodine.—A solution (Schacht's) composed of iodine 2 grains, iodide of potassium 6 grains, water 2 ounces, was employed. Violent moniliform contraction is produced, and the rounded mass into which the filament is transformed by contraction is stained yellow. In one instance the contracted mass consisted of two parts, a heap of transparent soap-bubbles and a yellow mass. There can be little doubt that the iodine and not the iodide of potassium is physiologically active in this solution. When diluted so that the iodine is about in the proportion [illegible] per cent., the solution is not poisonous, or only slightly so. It is known to have stimulating but not poisonous effects on germinating seeds.[1]

Alcohol.—Strong contraction is produced by irrigating with a

[1] Heckel, 'Comptes rendus,' 1875, p. 1170.

drop or two of methylated spirit. The subsequent effect of alcohol has puzzled and astonished me more than any other point in this research. First of all, the contracted mass seated on the top of the gland turns of a greenish colour. It then begins to diminish in size, and ultimately either almost or quite disappears. At first I was repeatedly deceived by this appearance, and believed that the filament was actually retracted within the gland. What really happens is that a great part of the filament is dissolved by the alcohol. The reaction with alkanet shows that resin is contained in the filaments. I presume that it is spread through the protoplasm of the filament, and corresponds to the metaplasm of Hanstein, or is intimately connected with the protoplasm in some other way. The results of treatment with alcohol seem to show that the quantity of resin is very large compared with that of the protoplasm. In some cases a minute shrivelled ball remains after treatment with alcohol; in other cases the contracted filament breaks loose and floats away before the alcohol has completed the solution of the resin contained in it; in a third set of cases the whole of the contracted filament disappears under the influence of alcohol. I know not how to explain this phenomenon. The summit of the gland is sometimes hollowed out slightly, and is difficult to examine accurately with high powers; it is possible that the minute remnant of protoplasm remaining after the resin is dissolved, and which would necessarily be shrunk by the alcohol, might be overlooked within the hollow on the summit of the gland. Again, it is conceivable that if the resin is very intimately distributed throughout the substance of the filament, its sudden removal by a powerful solvent might cause the disintegration of the remnant of protoplasm.

In a filament killed by osmic acid in an extended condition, and which was certainly dead (as it did not contract with 20 per cent. acetic acid), an effect of alcohol was seen which I cannot explain. The specimen was irrigated with methylated spirit with the intention of dissolving the resin of the filament and leaving a protoplasmic skeleton in an extended position. But the filament ran together in a manner which could not be verbally distinguished from contraction, although it had more the appearance of a filament of spun glass melting into a button than the normal act of contraction.

Chloroform.—Applied in the form of a vapour, choroform causes contraction. A thin transverse section of a young leaf was suspended by means of a drop of water to the under surface of a thin glass cover, forming the roof of a gas chamber. The chamber had the usual arrangement of tubes, one being connected with a washing bottle (in which the chloroform is placed, covered by a layer of water), the other either with the mouth of the ob-

server or with an aspirator. Observations made in this way established the fact that the vapour of chloroform causes contraction of the filaments. I recorded in one case that the filament under observation "did not contract directly I tasted the chloroform." The following observations show that chloroform produces a temporary narcosis of the filaments:—August 9th, 4.30 p.m. A filament was made to contract by the vapour of chloroform; by next morning at 9 a.m. it had altered in shape, being more elongated than when it first contracted, although it had by no means recovered its original whip-like form. On drawing chloroform through the chamber it contracted again. During this aspiration, a fully extended filament was seen to contract;[1] this filament had escaped the effect of the previous day's chloroform, as it had not then been protruded. Pure air was then rapidly drawn through the chamber, and by one o'clock the second contracted filament had partially assumed an elongated form, and was again made to contract by aspiring the chloroform.[2]

Glycerine.—A preparation was irrigated with glycerine, and a filament was seen to contract slowly, a sluggish-looking beading making its appearance. It ultimately became spherical, and remained unaltered for half an hour; it was then thoroughly irrigated with water, and still continued unchanged in appearance.

Syrup of sugar also produces contraction.

Quinine.—An aqueous solution of $\frac{1}{10}$ % of sulphate of quinine was employed, and contraction was observed in several cases. This result agrees with my father's observation that quinine is poisonous to Drosera.[3]

Camphor.—This substance was tried because my father has shown it to be a powerful stimulant to Drosera.[4] The washing bottle connected with the gas-chamber was half filled with water, in which a few lumps of camphor were floating; an atmosphere strongly impregnated with camphor was thus produced. The filament could not be made to contract by drawing the camphor-laden air through the chamber. A $\frac{1}{10}$ % (*i.e.* natural) solution of camphor was prepared, and by irrigating with this fluid contraction was distinctly and repeatedly produced. Conwentz has shown that camphor is a poison to the cells of *Cladophera fracta*[5].

[1] Contraction was here preceded by an unusual appearance which may be best described as a wrinkling, and is different from the moniliform contraction.

[2] There is nothing very special in the narcotizing influence of chloroform, for filaments half killed by dilute acids have occasionally been observed in a sluggish, narcotized state.

[3] 'Insectivorous Plants,' p. 201.

[4] Ibid., p. 209.

[5] 'Bot. Zeitung,' 1874, pp. 401, 417. Göppert seems first to have observed the poisonous effect of camphor on plants.

It is certainly poisonous to the glands and filaments of the teasel; but the latter are not excited by it as is the protoplasm in the tentacles of Drosera.

Curare.—A solution which had been used for curarizing frogs was employed to irrigate preparations with; it made the filament become slightly transparent, as if effected by ammonia, but did not paralyse or kill them. Curare is not poisonous to Drosera.[1]

Cobra poison.—A solution of about $\frac{1}{4}$ % was used for irrigation; it produces a peculiar form of contraction, with an intense wrinkling, and zig-zag appearance of little darting side filaments. It is not poisonous, and the filament shoots out again; it appears to be a powerful stimulant to the filaments, and this agrees with my father's observations on its extraordinary exciting effects on the protoplasm in the tentacles of Drosera.

Strychnine.—A solution of 1 % of acetate of strychnine was prepared, but the salt was not all dissolved, and the solution used was probably ·75 %. In some of the experiments, simple contraction was the result. But in several instances a remarkable phenomenon occurred. The filament began to contract, and then suddenly became motionless, being killed in a partly extended condition. The filaments were certainly dead, for they could not be made to contract by subsequent irrigation with *strong* acetic acid. This fact is important, for it shows that the contraction ordinarily due to acetic acid is not a chemical effect on the substance of which the filament is composed. For it is extremely unlikely that both osmic acid and strychnine should possess the power of hindering the *chemical* effect of acetic acid. On the other hand, the behaviour of the filaments with strychnine agrees to some extent with that of the tentacles of Drosera. My father found that a solution of acetate of strychnia (stronger than $\frac{1}{5}$ %), when applied to tentacles which had begun to move, allowed the latter to go on bending for a short time, and then killed them in a semi-contracted state.[2] In a few cases the filaments were rendered sluggish, without being killed by the strychnia solution, and a parallel effect was noted by my father in Drosera. Strychnine has the same power as ammonia of causing the appearance of drops of resin in the epidermic cells.

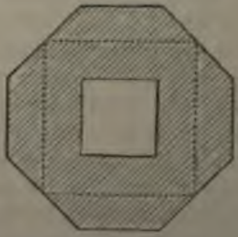
Heat.—In 'Flora' of last year (1876, p. 177) there is a careful research by Velten on the effect of heat on the streaming of protoplasm. He discusses various instruments for the examination of microscopic objects at different temperatures. He concludes that the most accurate are Sachs' heating-box ('Warmkasten'), and a modification of an apparatus of Nägeli's. The

[1] 'Insectivorous Plants,' p. 205.
[2] Ibid., p. 200.

'Warm-kasten'[1] is described in Sachs' 'Text-book of Botany,' Eng. Tr. p. 658. Velten's instrument is fully described and figured in 'Flora' (loc. cit.)

In my observations on the filaments of the teasel I have made use of both of the above apparatus; in this way, no serious error can occur. If the filaments were liable to contract spontaneously it would, of course, be impossible to make any trustworthy experiments, but this is distinctly not the case; the filaments remain extended with great constancy for long periods of time. Again, if they contracted when washed to-and-fro by

[1] Mr. Hawksley has constructed a box of this description for me, which answers admirably. At his suggestion it was made of carefully soldered tin-plate, which is said to be more durable than zinc if care is taken to drain the water out thoroughly after use. Mr. Hawksley has also substituted tin-plate lined with felt for the cardboard cover. According to Velten, the projecting portion of the tube of the microscope ought to be enveloped in felt to prevent undue cooling of the objective. Velten's apparatus is more simple than Sachs', and can be fitted up by any one for himself. A small glass vessel is placed on the stage of the microscope, the object to be examined is supported on a wooden frame, so that when the vessel is filled with water the object is surrounded by it on all sides, and the objective has to dip beneath the surface of the water like an immersion lens. The temperature is regulated by a current of hot water flowing in at the bottom, and a siphon carrying off the surface-water at the opposite edge of the vessel. Both tubes are provided with taps, and the water should be made to flow by drops and not in a quick continuous current. A thermometer is kept in the water close to the object. Velten cemented his thin cover-glass to prevent the preparation under observation being disturbed. I have found it more convenient to employ the following device:—A piece of stout lead-foil is cut into the shape shown in the woodcut. The object is



Lead-foil clamp for holding a microscopic object between two thin glass covers.

mounted between two thin glass covers and placed over the square aperture in the lead-foil; the four flaps are then gently bent up (the hinge-lines are dotted on the figure) so as to clamp the glass slides together, and the object can now be placed in water without any danger of the cover-glasses separating. This plan has the advantage of leaving the preparation accessible to re-agents after the heating experiment has been concluded, and from being between two thin glasses the object is rapidly affected by the changes in temperature of the surrounding water.

currents in the water in which they are mounted, observation would be difficult, at least, with Velten's apparatus; but this is not the case, for I have often seen the filaments violently shaken by the current without contracting. In the following experiments I thought it necessary to give the time at which the various temperatures were attained, because Kühne[1] has shown that time is an important element in heat experiments on protoplasm.

Experiments with Velten's apparatus.

In both 1 and 2 the record of experiment begins when the vessel had been filled with warm water.

Experiment 1.—Aug. 19th.

Time.	Temperature. C.	
4.26 p.m.	34°	Filament extended.
4.36	40	"
4.44	45	"
4.58	56	Filament contracted.

Experiment 2.—Aug. 20th.

12 noon	39	Filament extended.
12·5′ 30″ p.m.	43	"
12.8′ 15″	45	"
12.15′	49	"
12.20	52	Filament partially contracted. Observation continued on a different filament in same preparation.
12.35	56·5	Filament extended.
1.P′	57	Filament contracted.

Experiment 3.—Nov. 27th.

9.35 a.m.	12	Specimen mounted in cold water, a current of cold water flowing through vessel. Filament extended.
10.15	12	Filament still extended.
10.20	31·5 or 32	Filament and another on neighbouring trichome contracted; vessel of water was then allowed to cool somewhat.
10.25		The filament extended again.
10.37	28·5	Filament contracted.
11.29	19	Filament appeared again. Between 10.37 and 11.29 it had been subjected to the temperatures shown in Experiment 4.
11.41	17·4	Filament still extended.
11.43	27	
11.44	30·5	Filament contracted.
11.47	45·2	After 11.47 vessel allowed to cool slightly.
11.50	38	A fresh filament found in the same preparation, still extended.
11.52	41·7	

[1] 'Das Protoplasma,' 1864, p. 103.

Time.	Temperature. C.	
11.53′ 30″	44	Filament contracted; as are all the filaments in this preparation.
11.59	50	After 11.59 vessel allowed to cool.
12.20 p.m.	25	All the filaments (2 in number) contracted.

Nov. 28th.

5 p.m.	cold	Two filaments slightly re-extended; they were therefore not killed by temperature of 50°.

Experiment 4.—Nov. 27th.

10.38′ 15″	30·5	A filament in the preparation used in Experiment 3 still *extended.*
10.41′ 15″	35·5	Filament contracted. Nineteen filaments on this section of leaf contracted, but one is found still extended.
10.43	34	Filament extended.
10.45	32	"
10.46′ 30″	36	"
10.48′ 45″	39	"
10.51	40	"
10.52	41	
10.54′ 30″	42·5	Filament contracted.

Experiment 5.

3.20	cold	A number of filaments extended.
3.32	"	Filaments still extended.
3.34	17	"
3.37	38·5	"
3.39	47	Several filaments contracted.
3.40	47·5	More filaments contracted.
3.40′ 25″	48·5	All contracted. Vessel of water allowed to cool.
5.53	12·3	A single thick, partially expanded filament.
5.56	21·2	Filament still extended.
5.58′ 30″	27	Filament contracted.

Experiment 6.

6.3	16·2	No filaments visible.
6.24	11·8	A filament extended.
6.26′ 30″	18	
6.35	23·5	Filament contracted. Observation immediately transferred to another filament (extended) in the same preparation.
" 30″	23·2	
	27	This, the second filament, contracted. Observation transferred to third filament.
	27	Third filament extended.
	30	"
	32·8	"
	35	"
	37	Third filament contracted.
	36·2	Extended again.
	42	Contracted (owing to a mistake in observing, it may have contracted at a few degrees lower), water having cooled since 7.5. Filament still contracted.

The important result derived from these experiments is that, although there is most remarkable variability in the temperatures at which contraction took place, *yet no filament withstood without contraction a temperature of more than* 57° *C.* No increased activity was observed at lower temperatures.

The following experiments were made with Sachs' heating box:

Experiment 7.

Time.	Temperature. C.	
12 26	47	Filament extended.
12.37	55	Filament contracted. The microscope was then removed, another specimen mounted and then replaced.
12.45	56·8	Filament extended.
12.54	56·9	Filament contracted.

Experiment 8.

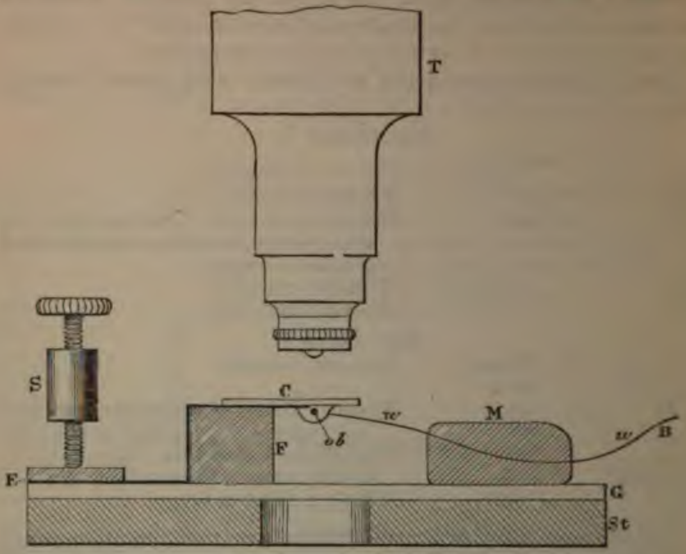
10.55 a.m.	T. of room.	Filament extended.
11.1′ 30″	36·5	"
11.18	35	Filament contracted; microscope removed
11.23	38	and replaced. Fresh filament observed.
11.35	37	Fresh filament contracted. Microscope re-
11.40′ 30″	40	moved and new filament (3rd) observed.
12.1	43·5	Filament contracted.

The average temperature of contraction from the experiments with Sachs' box is 45·4°, the average for the series with Velten's apparatus being 38·7°, the average of the whole of both series being 42° C.

Electrical stimulation.—By using a modification[1] of the electrodes usually employed in microscopical work the filaments were easily subjected to the influence of the induced current. Clear and unmistakeable contraction was thus produced, and the observation was several times repeated. No contraction was produced until the current was approaching the strength at which water is decomposed. The filaments were not thrown into a state of activity by weaker currents; and this agrees with Heidenhain's observations on the hairs of Tradescantia (quoted by Sachs, 'Physiologie Végétale,' p. 85). He found that weak currents produced no effect on the protoplasm, while strong currents rapidly stopped all movement. On the other hand, Brücke and Max Schultze (quoted in Sachs, 'Phys. Vég.', p. 86)

[1] I succeeded so easily with this modified arrangement, when I failed with the ordinary form of microscopic electrodes, that it seems worth describing. I am indebted for the suggestion to Prof. E. Ray Lankester. He pointed out that the object to be examined might be placed in a drop of water hanging from the under surface of a thin glass cover, just as in the gas-chamber. One electrode is fixed to the under surface of the thin glass, the other is movable and is brought cautiously into the field of vision until it closely approaches the object. This arrangement is shown in the accompanying woodcut, which gives the instrument in section.

found that delicate trembling filaments darted out from the



Microscope electrodes.

St, stage of microscope; G, glass slip; F, block of cork; M, lump of modelling wax; *w*, *w*, fine wire passing through M; B, end of *w* connected with battery; E, the other electrode fixed to F; *ob.*, the object to be examined hanging in a drop of water; C, thin glass; T, tube of microscope with objective; S, a Stricker's binding screw; G is an ordinary glass slip, to which is cemented a cubical block of cork, F, which supports the *fixed* electrode. The latter is represented by the black line, E. It consists of a sheet of platinum foil nearly as wide as the glass slip to whose upper surface it is cemented, reaching from E to the fixed block, F, it then passes up the vertical external face of F, and bending at right angles ends in a point, and is cemented to the upper surface of F and the under surface of the thin glass-cover, C. The movable electrode consists of a block of modelling wax, M, pierced by a finely pointed wire, *w* (such as is used for clearing the canula of a hypodermic syringe). To use the instrument, the object is placed at *ob*, suspended in a drop of water, and *w* and E are connected with the battery or Du Bois coil. For connecting the platinum plate E with the coil a single one of Stricker's binding screws may be used. The point *w* ought to stand up like a spring, so that by sliding up M, and slipping *w* beneath the glass cover C, the point of *w* presses gently against the under surface of C (*w* does not touch the under surface of C in the figure). Supposing that a section of a teasel leaf is hanging at *ob*, the point of *w* can be made to approach any desired filament; when this is effected the cube of modelling wax, M, is fixed by a little firm pressure, to the glass slide, and on closing the key the filament is subjected to the action of the current.

streaming protoplasm in the hairs of the nettle when subjected to an induced current.

Mechanical stimulation.—By getting a filament exactly into the centre of the field of vision, and screwing the objective down so as to press on the cover-glass, the filament can be made to contract. This observation was repeated several times, and in some cases, by focussing up rapidly, the filament was observed in the act of contraction from the effect of the previous pressure.

Amœboid or aggregation movements.—This term is applied to a series of appearances which, though not essentially differing from the moniliform contraction already described, are more conveniently considered separately. It would, perhaps, be better to call them simply aggregation movements, since they more closely resemble the changes observed in the tentacles of Drosera when excited by the absorption of nitrogenous matter than any other phenomena.

The most striking variety of aggregation-change which occurs in the filament is due to the action of dilute solutions of carbonate of ammonia, or of an infusion of meat, and is partially produced by weak solutions of carbonate of potassium and sodium. A detailed experiment will best illustrate the nature of the phenomenon in question. July 10th, 1 p.m., a young teasel "cup" was cut from the plant by severing, both below and above the bases of the leaves, the stalk which passes like a vertical axis through the cup. The small section of the stalk, thus freed from its attachment to the plant, was divided in a median plane in such a way that one half of the stalk remained attached to each leaf; one half was placed in a solution of carbonate of ammonia ($\frac{1}{2}$ %), and the other in distilled water. On July 11th, at 8 a.m., transverse sections were cut from both specimens and examined. In the water specimen the filaments were long and delicate threads, whereas in the sections taken from the half immersed in the ammonia solution they presented a totally different appearance. The glands were surmounted by transparent sausage-shaped and rounded masses of low refractive index. Subsequently sections were cut from the water specimen and were irrigated with $\frac{1}{2}$ % of carbonate of ammonia. A filament was seen to undergo moniliform contraction, and then became partially extended; nearly all the filaments in the preparation became changed into variously shaped transparent masses, and distinct changes of shape were seen. A few transparent masses produced by immersion for an hour, in $\frac{1}{4}$ % solution of carbonate of ammonia, are seen in fig. 7. Remarkable changes of form occur; large bulging masses quite alter their shapes, snake-like filaments disappear and others appear, spheres coalesce [illegible] another, and, in fact, the mass of filaments is in th[illegible]

an hour or so completely transformed and altered in appearance. The glands are coloured of a faint green by the ammonia solutions. The results obtained with fresh and putrid infusions of raw meat have surprised me still more than the changes produced by ammoniacal solutions.

July 18th, 10.50 a.m.—Sections cut from a young leaf of second year's growth were mounted on slides, some in distilled water, others in an infusion of raw meat; owing to a mistake in the notes I cannot say whether it was a fresh or putrid infusion. The specimens were examined at 3.30; those mounted in water showed only fine whip-like filaments, whereas in the meat specimens there were found enormously long and bulky filaments something like those shown in fig. 11. The same kind of result was obtained by five hours' immersion in *fresh* infusion of meat, also in the following instance with putrid infusion.

July 20th (between 11 and 12 noon).—A young 'cup' was divided in the manner described above, one half being placed in distilled water the other in putrid meat infusion. July 23rd, 10 a.m. (about seventy hours after immersion).—Sections were cut from both halves and examined. In the meat specimens there were astonishing masses of spherical and pear-shaped transparent filaments with some rope-like ones as much as ·96 mm. ($\frac{1}{26}$ inch) in length. Changes in form and in position were seen to take place. The masses exactly resembled in appearance the transparent filaments which are seen attached to glands after irrigation with dilute solution of carbonate of ammonia, but here they were attached to no glands; they seemed to have been poured out in enormous quantities and to have freed themselves from all attachment. Unfortunately no record was kept of the condition of the corresponding half of the 'cup' which had been in distilled water; but from this fact it is probable that they presented the normal appearance with thread-like or slightly moniliform filaments. On July 26th, at noon, the glands appeared to be dead, but the protoplasmic masses (which were not attached to glands) were still in movement. Fig. 11 was sketched with the camera lucida. The masses were bright and highly refracting. A curiously moniliform mass (not figured in the plate) was also seen in very rapid movement. One mass was made to run into a sphere and was almost or entirely dissolved by methylated spirit. As I found that an infusion of putrid meat was faintly alkaline it appeared possible that the results obtained with ammonia, with carbonates of potassium and sodium, and with meat infusions, were all due to their alkalinity. But this is certainly not the case, as precisely the ordinary results were obtained with meat infusions carefully neutralised with dilute citric acid. Why solutions of carbonate of potassium and sodium should

have the same effect as nitrogenous or ammoniacal solutions, I cannot say. These salts produce aggregation in Drosera and in this way they again resemble ammonia in action.

It will be seen from the above account that the effect of infusions of meat is to cause an enormous and probably abnormal production of filaments which usually free themselves from their attachment. In some cases the filaments are very transparent, like those produced by ammoniacal solutions; in other cases they do not differ in refractive index from the ordinary filaments, which are usually bright and highly refracting. In the latter case the filaments resemble those shown in figs. 8, 9, and 15; in fig. 15 are represented the rapid movements of a free and unattached filament. The change from fig. 8 to fig. 9 took place in about half an hour; the curiously beaded filament in fig. 8 had doubtless originally issued from the trichome as a simple whip-like body. The aberrant forms produced by slow contraction are exemplified in fig. 12, for in this case also there is little doubt that the mass was originally a simple filament. I am, unfortunately, unable to say to what cause this latter kind of movement is due. I have seen curiously shaped or actively moving filaments in fresh specimens mounted in distilled water; this seems to negative the view that the changes in question are due to the absorption of nitrogenous matter. But it must be remembered that a transverse section of a young leaf mounted in water is practically exposed to a nitrogenous fluid owing to the death of the protoplasm killed in the young leaf-cells in making the sections. I can only repeat that these changes do under some unknown conditions certainly occur, and that somewhat similar changes are certainly brought about by immersion in infusions of meat and solutions of carbonate of ammonia.

Nature and physiological relations of the filaments.—I have now given some account of the physiological behaviour of these remarkable filaments. Before proceeding further it will be well to attempt the discussion of the question, what relation does the power of protruding filaments bear to other processes of vegetable physiology? When I first observed the filaments I found it extremely difficult to believe that they were protoplasmic organs issuing from the glands. I was even inclined to suspect that they might be parasitic organisms of some unknown kind which merely fixed themselves on the summits of the trichomes to avail themselves of the putrescent fluid retained by the connate leaves of the plant. Such facts as those given in one of Mr. Dallinger's memoirs,[1] should make one cautious in rejecting such a theory, nevertheless I believe it may certainly be dismissed. It i[illegible]-

[1] "Practical Notes on Heterogenesis," 'Popular Science Rev[illegible] 1876.

sible to believe that parasitic organisms would seat themselves almost without exception on the same part of the gland. Some of the very rare cases in which a filament was seen seated on the side of a trichome proved after all not to be exceptions to the rule; for, by making them contract, they proved to be attached by delicate connecting filaments with the summit of the gland. It is also a very convincing fact that the trichomes of the fig. 1 type never produce a filament, although they are apparently as well fitted as the fig. 2 type for the abode of a parasite. Again, the fact that filaments are found on the leaves of seedlings reared in a hot-house and far from their parent-plants (from which they might otherwise be infected with the supposed parasite) seems to me strongly against the parasite hypothesis.

Putting aside any view of this nature, we seem to be reduced to two theories—(1) That the filaments are protrusions of the resinous protoplasm of the glands. (2) That they consist of a resinous secretion of gelatinous consistence; and that the movements which occur are not due to vital activity inherent in the substance of the filaments, but are due to purely mechanical causes. The movements might be supposed to be similar in kind to those observed by Professor Ray Lankester[1] in the coloured blood-corpuscles. He found that the merest trace of the vapour of ammonia caused a wrinkled wave to travel over the surface of the corpuscle, simulating contraction. A stronger dose causes the protrusion from the corpuscle of processes which collapse when acetic acid is substituted for ammonia. These movements are believed by Professor Lankester to be purely mechanical in nature. As another instance of purely physical effects closely similar to "vital" movements may be cited Sachs' recent research, 'Ueber die Emulsion Figuren, &c.'[2] Previous investigators had believed the movements of swarm-spores in relation to light were truly vital in nature. Sachs has, however, proved, by obtaining similar phenomena with emulsions of oil, that they are the direct physical result of slight differences in the temperature of surrounding objects.

I shall now briefly consider the behaviour of the filaments in relation to the above-mentioned theories, which may be called (1) the vital; (2) the mechanical theory.

In favour of the mechanical *theory* we have the fact that the filaments undoubtedly contain a large percentage of resinous matter, which might conceivably give rise to mechanical pseudo-contractions. Again, it might seem that there is a greater *à priori* probability of such pseudo-contractions occurring than of the protrusion of a highly resinous protoplasm through the

[1] 'Quarterly Journal of Microscopical Science,' 1871, p. 376.
[2] 'Flora,' Nrs. 16, 17, 18, 1876.

cell-wall of one of the higher plants. But the balance of probabilities is reversed when we inquire into the causes that induce the movements. For it is inconceivable that violent contraction should be mechanically or chemically produced by such different reagents as very dilute acids, alkalies, solutions of chloride of gold, sulphate of quinine, camphor, or by a temperature below 57° C.

On the other hand, the whole behaviour of the filaments (except the results of irrigation with alcohol) points to the conclusion that the movements are connected with living matter. In this point of view the more important features in the behaviour of the filaments are the following:

1. The "spontaneous" movements.

2. Contraction being produced by various reagents, such as acetic acid or sulphate of quinine in very dilute solutions, and by the vapour of chloroform.

3. Death in an extended or not fully contracted condition being produced by solutions of osmic acid and acetate of strychnine.

4. Contraction being produced by subjecting the filaments to a temperature below 57° C.; to the action of the induced current; to mechanical violence.

5. Not only do these agencies cause contraction, but the filament is reduced by them to a motionless condition, in which no farther contraction can be induced, and in which the filament swells up in consequence of the imbibition of water.

On the whole, the balance of evidence seems to me to be strongly in favour of the view that the filaments of the teasel consist of protoplasm in which a large proportion of resin is in some way mingled.

Probable functions of the filaments.—I shall now endeavour to connect the above-described phenomena with known facts in physiology, and to make a conjecture at what seems to be the most probable function of the filaments. The class of facts which appears to be most nearly related to the phenomena is that of secretion. There can be little doubt that the protrusion of filaments is closely related to the secretion of resin, for caps of accumulated resin are found on the summits of the glands, while inside the cells are spheres of the same substance. No one would hesitate to consider these crusts as resin secreted by the glands. But the filaments resemble these crusts in several ways, *e.g.* in refusing to be stained by ordinary dyes, in being coloured by alkanet and by iodine, and in being largely soluble in alcohol. Moreover, incrustations of resin are only found on that variety of gland from which filaments are protruded. The view is maintained by many physiologists that an act of secretion consists in the disintegration or death of protoplasm. Every mass of w[illegible]

ordinarily called protoplasm, or *plasma*, is made up of two distinct portions: one of these is truly living matter, and should alone be called protoplasm; the other is not alive, and is called metaplasm (Hanstein)[1]. According to Beale, all metaplasm must pass through the stage of protaplasm. But whether or not this be so need not here be discussed. It will be granted in either case that secretions may be formed by the metaplasm increasing so that the protaplasm is annihilated. Dr. Creighton's recent work[2] renders it highly probable that the secretion of milk takes place on this principle; a new plastid arises within a mammary gland-cell, and is entirely converted into oil. I would suggest that the secretion of resin is an example of a somewhat different form of protoplasmic secretion. I believe that the portions of protoplasm destined to give rise by disintegration and death to the secreted resin does not proceed at once to the full limit of disintegration, but that it issues from the gland while still possessed of some vitality. I am aware that many weighty objections may be raised against this view. It may be said that protoplasm containing so large an amount of lifeless matter could not exhibit activity. In support of this it might be pointed out, that the accumulation of large quantities of food-yolk in ova is associated with quiescence. Secondly, it may be said that the protrusion of living protaplasm is an inconceivably wasteful method of getting rid of a secretion.

I will first consider the former of these objections. The process of aggregation, as it occurs in the tentacles of Drosera, affords an example of loss of motility connected with an increase of metaplasmic matter. The spontaneously-moving masses of coloured protoplasm in Drosera assume under certain conditions a spherical form in which motion ceases, and this condition is associated with an increase in density, probably owing to the condensation of the accumulated metaplasm into smaller compass. This phenomenon seems to negative the view that the filaments of Dipsacus could possibly be active while containing a large quantity of resin. But from another point of view, this argument is not quite fair. The motionless aggregated masses in Drosera are so dense that they crack into star-like forms[3] when pressure is made on the cover-glass. But before this intense condition of aggregation was reached the metaplasm must have been at least moderately condensed, and in this condition the masses were still motile. There is another possibility which

[1] 'Bot. Zeitung,' 1868, p. 710.
[2] 'Reports of the Medical Officer to the Privy Council,' 1875, No. vi, p. 171.
[3] 'Insectivorous Plants,' p. 47. For figures of these forms see 'Quart. Journ. of Micro. Science,' July, 1876.

should be considered, namely, that the filaments may consist of a liquid core of resinous matter, surrounded by a tubular shell of protoplasm. Professor Ray Lankester, who was kind enough to examine preparations of living glands, suggested this idea. He remarked that the moniliform contraction gave him more the impression of a tube closing on its contents than of any possible contraction of a solid body. I think this view ought to be considered, though I am not at present inclined to accept it.

To return to the second of the above objections—viz. that the protrusion of protoplasm is an incredibly wasteful method of secreting. Two answers may be made to this objection. It must be granted that if a wasteful, it is also a rapid way of secreting, and it is impossible to know of how great importance it may be that what is probably an excretion should be rapidly eliminated. In the second place, it is quite possible or probable that the filaments have not adhered to their original function of removing waste products, but have assumed other functions. It is perfectly conceivable that a protruded mass, consisting in part of true, living, protoplasm, should, on finding itself surrounded by a nitrogenous fluid, absorb and transmit nutriment to the leaf. We know from my father's observations on Utricularia that the trichomes lining the bladders are markedly affected by the absorption of nitrogenous fluids. And we have the same kind of evidence in the case of the teasel. My father found that a weak solution of the poison of the cobra-snake had a powerfully stimulating effect on the tentacles of Drosera. A solution of about ¼ % produced more active aggregation than can be produced by any other means, except, perhaps, a moderately high temperature. The same solution of cobra poison was tried with the teasel; it not only produced a state of activity in the filaments as already described, but was certainly absorbed by the trichomes. At 4 p.m., when the solution was applied, the contents of the trichomes were merely granular, next morning the cells contained definite masses, which slowly changed their forms. (See fig. 10.) This appearance must be considered as "aggregation"; and when it is remembered that aggregation only occurs in the glands of Drosera, Pinguicula, Utricularia, &c., when excited, it must be allowed that we have evidence of the excitement of the glands of the teasel by the absorption of the cobra solution. But too much stress must not be laid on this phenomenon, as on some occasions it entirely fails with cobra solution, and is a very rare occurrence under any circumstances, and fig. 10 was drawn from a specimen simply mounted in *water* for two or three days. Moreover, it seems to have nothing to do with the filaments, for I have seen it on two occasions in the glands of the fig. 1 type. I may here

mention another phenomenon which I do not understand, but which is the almost universal result of treatment with $\frac{1}{4}$ or $\frac{1}{2}$ % solution of carbonate of ammonia. It consists in the appearance of numerous bright, highly refracting drops of resin in the epidermic cells, which gradually run together and form large spheres. They are very easily soluble in methylated spirit, and, no doubt, consist of the same resinous matter secreted by the glands. A similar effect was extremely well marked, and repeatedly seen in preparations mounted in 75 % solution of acetate of strychnia. No other substances seem to have the same power, and the phenomenon must remain unexplained. At first sight the protrusion of filaments, and the changes which occur in them, appear to be isolated phenomena unrelated to any known physiological process, except in a certain way with secretion. I believe, however, that some relationship must exist between the protrusion and amœboid movements of the filaments, and the process of aggregation as it occurs, for example, in the tentacles of Drosera. The physiological meaning of the latter phenomenon is at present unknown; we know, at least, that variously shaped protoplasmic (?) masses make their appearance and undergo incessant movement. If these masses were to traverse the external cell-wall, and protrude into the surrounding medium, they would closely resemble the filaments of the teasel. The following are the points of resemblance between the protruded filaments of the teasel and the aggregated masses of Drosera:

(1.) Both consist of homogeneous, highly refracting masses of protoplasm, imbued with a large quantity of metaplasm; the latter being fatty (?) in Drosera, resinous in Dipsacus.

Both are connected with glandular organs, which not only secrete certain substances, but also absorb nitrogenous materials.

The comprehension of the relations between the processes of protrusion and aggregation is rendered more difficult by the fact that true aggregation takes place within the trichomes of the teasel.

The production of filaments is not an unknown occurrence in the ordinary protoplasmic contents of cells. Max Schultze[1] describes in the stinging hairs of the nettle the appearance of a certain number of threads projecting from the parietal protoplasm into the cell-sap; their free extremities are swollen or clubbed, and they are in a state of trembling movement. These appearances are only seen when the electric current to which the hair is subjected is nearly strong enough to kill the protoplasm.

I have occasionally seen these internal filaments, for instance in a gland which bore also an ordinary external filament. By careful

[1] Quoted by Sachs, 'Physiologie Végétale' (French translation), p. 86.

focussing with No. 9 Hartnack I made certain that there was a filament actually inside the gland; and it was proved not to be outside by irrigating with methylated spirit, by which means the external filament was made to contract while the internal one was unaffected. The same appearance of trembling clubbed filaments was seen in one of the large conical hairs on the seedling teasel-leaf. Three of such filaments are marked by crosses in fig. 12; the largest of the three waved to and fro, and reminded me closely of one of the ordinary external filaments.

Relation between the general structure of the Teasel and the protrusion of filaments.—The conclusion to which the study of the filaments and the glands seems to lead is, that they are both capable of absorbing nitrogenous fluids. It will be well to consider whether or not the general structure of the teasel is in any way co-ordinated with this power.

In the first place, it is quite certain that the plant is well adapted for catching and drowning insects.[1]

The connate leaves form cups holding from 12 to 100 c.c. of fluid; the leaves are smooth[2] (although those of the seedlings are rough, with large prickly hairs) and are inclined so as to form a large angle with the horizon and a small one with the vertical; they form, therefore, two steep and slippery slides, leading to a pool of water. The stalk of the plant is covered with sharp prickles, but these cease where the stalk dips into the water in the cup. If it were not for the loss of the prickles at this point, a ladder of escape would be provided for the drowning victims. I have seen a beetle struggling to get out, and observed his tarsi slipping over and over again on the smooth stalk. The cups undoubtedly form a most efficient trap. In some wild teasels the following insects were found:—In one cup six large malacoderm beetles, from half to three quarters of an inch in length, one fair-sized caterpillar, and two flies; in another, seven of the same beetles, one earwig, a bluebottle fly, besides

[1] Prof. Kerner believes that the "cups" of the teasel are a protection to the flower against the attacks of ants and other wingless insects who might steal the nectar without benefiting the species. In his recent memoir, "Die Schutz-Mittel der Blumen gegen unberufene Gäste," in the 'Proceedings of the K. K. Zoolog. Botan. Gesellschaft, Vienna,' 1876, he supports, with strong arguments, the theory that many flowers are thus protected. He would, however, be the first to admit that a given structure may have developed through serving more than one useful purpose. It is curious that in the last century Erasmus Darwin should have remarked on the protective function of the "bason" formed by connate leaves of the teasel. He even alludes to nectar as one of the treasures to be guarded in this kind of way, although he was not, of course, aware of the true relations existing between flowers and insects. (See 'Loves of the Plants,' Note 6.)

[2] The glands do not make the leaves appreciably rough.

many smaller flies and much débris. A much larger number of insects were counted in some other teasel-cups, but the notes were lost, and the loss was only discovered when it was too late to make fresh observations. The water contained in the cups is almost always muddy from the débris of dead insects; and when the old leaves at the base of the stem wither, and can no longer hold water I have seen them swarming with Staphylinidæ and other refuse-eating beetles. I tried a number of experiments by taking a large number of the same kind of malacoderm beetles, and placing one half in water, the other in the fluid of the teasel-cups. The result showed that beetles are drowned much more rapidly in the teasel fluid than in pure water. Whether there is a narcotizing poison in the fluid, or whether, as is far more probable, the oiliness or stickiness of the decaying fluid causes the insect's spiracles to be blocked up, I cannot say. The fact that large slugs are occasionally drowned in the cups is in favour of the poison hypothesis, for I find that slugs, if dropped into the teasel-cups, can crawl up the smooth leaves.

From these various considerations I believe that the plant does profit by the insects caught in the cups. This question I hope to decide by a comparative experiment, in which a number of teasels raised from seed under similar conditions will be divided into two lots, one half being starved and the other fed with insects or pieces of meat.

But whether or not the glands which find themselves immersed in the putrid fluid of the teasel-cups take advantage of their position to absorb nitrogenous matter, there is no doubt that the protrusion of filaments is not a habit originally developed for this special purpose; for, as above explained, the glands on the seedlings which do not form cups, and therefore catch no insects, have well-developed filaments. But it may be answered that they are developed in the seedlings by a kind of inheritance from the adult plant. Even if this reasoning were permissible the conclusion that the filaments are specially adapted in relation to the leaf-cups is demolished by the following fact, already alluded to. The other British species of teasel, *D. pilosus*, has no leaf-cups, and therefore cannot entrap insects, yet the leaves bear glands, and these produce contractile filaments. If we grant that the filaments have any power of absorbing nitrogenous fluids, and this can hardly be denied, the only theory that suggests itself is the following:—That the filaments absorb the salts of ammonia from the rain-water and dew which fall on the leaves, and that it is this power which is modified in the adult plant so as to enable the filaments to take advantage of the animalized fluid retained by the leaf-cups. It has been already stated that filaments can issue from the glands when the leaf is merely *damp*. It does

not, therefore, seem impossible that an elongated filament should crawl or spread itself over the surface of the leaf, its proximal end remaining attached to the gland; and in this way ammonia might be absorbed and transmitted to the gland, from the dew or rain collected on the leaf. The following observation seems to show that the filaments can adhere to smooth surfaces; and this faculty, in conjunction with their powers of contraction and extension, would enable them to crawl on the surface of the leaf. A free or unattached filament being in the field of the microscope, the preparation was irrigated with methylated spirit. The filament did not float away with the current, but evidently adhered to the under surface of the cover-glass. When the alcohol reached it the filament actually contracted against the force of the current, showing how firmly it was attached to the glass.[1]

Schlösing[2] has shown that the leaves of the tobacco-plant, when supplied with the vapour of carbonate of ammonia, yield on analysis a greater amount of nitrogen than other plants not thus treated. My father remarks that the vapour may be, perhaps, absorbed by the glandular hairs on the leaves. Dr. Gilbert[3] also states that Adolph Mayer has "experimentally shown that plants can take up nitrogen by their leaves from ammonia supplied to them in the ambient atmosphere." There is, therefore, nothing extraordinary in the belief that the leaves of the teasel absorb ammonia from the atmosphere; the novelty is merely in the method of absorption, viz. by protoplasmic filaments.

It is therefore important to know whether the amount of available ammonia in the atmosphere is sufficient to be an item in the food of the plant. MM. Schlösing and Mayer (as quoted by Dr. Gilbert) appear to believe that the absorbing action "takes place in a very immaterial degree in natural vegetations." This may be from a lack of absorbing organs on the part of the leaves, or from the small quantity of ammonia which is available for

[1] This observation suggested that the filaments might in the adult plant crawl over the dead bodies of the drowned insects, and thus absorb a strongly nitrogenous nutriment. I therefore cut thin sections of roast meat across the fibres, and placed the minute fragments thus obtained round and among the glands on a section of a teasel-leaf. But not a single filament applied itself to a piece of meat. I also thought that the filaments might have the power of seizing minute granules floating in the muddy water of the cups. I tried a number of experiments in the hopes of deciding the question. Preparations were irrigated with finely divided carmine suspended in slightly ammoniacal fluid, but no particles were ever seized by the filaments.

[2] 'Insectivorous Plants,' p. 353; for the original see 'Comptes rendus,' June 15th, 1874.

[3] Address delivered at South Kensington at the Science Conferences, 1876.

absorption. Dr. Gilbert (p. 5) gives the amount of ammonia which falls in rain and minor aqueous deposits per acre at Rothamsted as 6·46 pounds per annum. Boussingault[1] found ·00079 grm. per litre of ammonia in rain water in the country districts of France. In dew he found as much as from ·001 to ·006 grm. per litre. The average of three analyses here given of the amount of organic matter in rain water is ·028 grm. per litre. Is it not possible that some of this organic matter (which causes rain water to putrify when kept) may be absorbed by the filaments? On the whole, it does not seem impossible that a plant should derive benefit from the nitrogen in the rain and dew which falls on its leaves.

Conclusions.

The following is a summary of the results which I believe to be established on a reasonable basis of probability:

1. That the filaments are not parasitic organisms, but are the normal productions of a particular form of glandular trichomes on the leaves of the seedling and second-year plants.

2. That they consist of protoplasm in some way intimately connected with resinous matter.

3. That the function of the protoplasmic portion of the filament was originally to assist in the act of secretion, but that it has been subsequently utilised by the plant as a mode of nutrition.

4. That the protoplasmic filaments have the power of absorbing nitrogenous matter, and that in the seedlings they probably absorb ammonia from the rain-water and dew. In the adult plants they absord the products of the decaying insects for the capture of which the plant is adapted.

5. That some obscure correspondence may exist between the protrusion of the filaments and the process of aggregation.

NOTE TO MR. FRANCIS DARWIN'S PAPER.

I beg leave to say that I have witnessed almost all the facts described in the foregoing paper, and can vouch for their accuracy. To the best of my judgment, the whole case is a most remarkable one, and well deserves the attention of physiologists.

CHARLES DARWIN.

[1] 'Watts' Dict. of Chemistry,' v, p. 1014-15.

NOTES *on the* STRUCTURE *of* SEVERAL FORMS *of* LAND PLANARIANS, *with a* DESCRIPTION *of* TWO NEW GENERA *and several* NEW SPECIES, *and a* LIST *of all* SPECIES *at present known*.

By H. N. MOSELEY, M.A., F.R.S., Fellow of Exeter College, Oxford. (With Plate XX.)

HAVING made a special study of the structure of the Land Planarians of Ceylon, the results of which were published in the 'Phil. Trans. R. Soc.' of 1874,[1] I was naturally led to extend my observations of the group during the voyage of H.M.S. 'Challenger.' I collected specimens wherever the opportunity offered, and made such observations on them as my other work permitted. The present paper contains the results of these observations, which are very far from complete, since I have not yet been able to make an extended investigation of all the specimens which I preserved for that purpose.

Land Planarians of Brazil.

In September, 1873, during the stay of H.M.S. 'Challenger' at Bahia, I found abundance of a species of Geoplana, apparently hitherto undescribed, and a single specimen of a second species undetermined was found by Dr. von Willemöes-Suhm. The new species, *Geoplana flava*, was found in moist shady places in the neighbourhood of Bahia, and especially beneath the sheathing bases of the leaves of Bananas, which retreat is that selected also most usually by the Ceylon land planarians of the genera *R. Rhynchodemus* and *Bipalium*. A few specimens were also found crawling on palm stems in the daytime in very rainy weather, but in places where there was very little light.

I repeated the experiments made by Fritz Müller as to the ciliation of the surface of the animals, using, however, very small fragments of paper to place on the animal to indicate the direction of currents, instead of arrow-root meal, and with a somewhat different result.

Fritz Müller ("Beiträge zur Kenntniss der Landplanarien," Dr. Max Schultze, 'Abhn. der Naturforschenden Gess.,' in Halle 4 Bd.) found that the meal moved on the dorsal surface of the animal forwards and somewhat outwards, on the ventral surface backwards. When the animal was resting in a contracted and quiescent state, I found that no ciliary motion was shown on the

[1] "On the Anatomy and Histology of the Land Planarians of Ceylon; with some Account of their Habits, and a Description of Two New Species, and with Notes on the Anatomy of some European Aquatic Species." By H. N. Moseley, 'Phil. Trans. Roy. Soc.,' 1874, p. 105.

dorsal surface at all, but that immediately the animal began to crawl the indicating fragment of paper began to move.

In the species examined by me the ciliary action had a forward direction only in the anterior region of the dorsal surface, in the posterior region the indicator moved always backwards towards the tail. In all regions of the dorsal surface it moved outwards, as was observed by Fritz Müller at the same time as backwards or forwards, and was thus rapidly thrown off at the side of the body, the dorsal cilia apparently subserving especially, this function of the speedy removal of foreign substances from the surface of the body. The ciliary current on the under surface of the body flowed directly from before backwards, so that the indicator moved parallel to the middle line of the body. The current was much more rapid towards the hinder extremity.

The animal moved to a large extent by muscular action, the body alternately contracting and expanding during motion. When moving it lifted its anterior extremity often, just as does Bipalium, and moved it to and fro as if to feel or see its way.

When the anterior extremity of the body was cut off the remainder of the animal seemed still to move with definite purpose, avoiding obstacles and retreating from the light, whilst the cut end was raised and thrust in various directions as if to search for an object on which to climb.

Eye-spots were present in two elongate patches on either side of the head, and scattered along the whole length of the body on its lateral margins.

A transverse section of the fresh animal was examined in saliva. Cilia were present over the entire dorsal surface of the animal, but are there very short and difficult to see, whereas they are very long and strong on the ventral surface. The free surface of the gastric lining of the digestive canals was ciliated.

Large cells were seen in the parenchym of the body, which had a finely granular content, with a nucleus and nucleolus. These cells showed active amœboid movements when isolated by pressure, and at the same time a rapid movement of their granules somewhat like a cyclosis.

The pigment present was in the form of small rounded masses as in Bipalium.

Unfortunately no specimens of the geoplana were obtained which had their generative organs fully developed, all the specimens being young.

The muscular arrangement appears to resemble that occurring in the New Zealand Geoplana. There is no ambulacral line, the external longitudinal muscles are evenly developed all over the sole or under surface, and but little over the dorsal region. The lateral organs or primitive vascular system are diffuse and closely

similar to those in Geoplana N. Zealandiæ. Rod-cells closely similar to those of the South African land planarians were observed in this species. They contain each several long spirally-wound rods (Pl. XX, fig. 15). Others occur (Pl. XX, fig. 14) in which the rods are short and straight. Cells were observed with the rods in all stages of development (Pl. XX, fig. 16). The rods when short show a tendency to spiral winding.

Description of the Structure of a New Zealand Land Planarian, Geoplana Traversii.

Captain Hutton, in his essay on the New Zealand fauna, mentions the occurrence in New Zealand of two or three species of Land Planarians, one or two of which he states belong to the genus Bipalium.[1] This short reference is as far as I know the only notice of these Planarians which has hitherto been published.

When H.M.S. 'Challenger' was at Wellington, Mr. W. T. L. Travers, F.L.S., gave me two specimens of a species of Land Planarian occurring in the neighbourhood of Wellington. Both of these were sexually mature and in sufficiently good preservation to enable me to make out the anatomy of this form with considerable completeness.

The Planarians are of elongate form, broadest in their middle and gradually attenuated from thence towards either extremity. They are flattened below and slightly rounded above, and thus resemble the other members of the genus Geoplana in general form. The body is marked with longitudinal stripes, as in most Land Planarians. The length of the largest specimen obtained was 3 cm., and its extreme breadth 8 mm.

The mouth, or opening of the sheath of the pharynx, is placed in the centre of the body and the generative aperture at a little less than half the distance between the mouth and the posterior extremity. There is no ambulacral line, the whole under surface acting as one uniform muscular sole.

Numerous eye-spots are present; these are placed in a single row composed of twelve or more along the front margin of the head and in an elongate patch on either side of the head made up of two or three rows placed one above another, and containing about forty eye-spots (Pl. XX, fig. 1). Eye-spots are further scattered more sparsely on the lateral margins of the body, along its entire length posteriorly to this patch.

The patch itself is thickly beset with pigment which has an irregularly ramified disposition, but amongst which clear trans-

[1] The Geographical Relations of the New Zealand Fauna," by Captain F. W. Hutton, C.M.Z.S., 'Trans. New Zealand Inst.,' vol. v, 1872, p. 23.

parent oval spaces entirely free from pigment occur, and in these the eye-spots lie (Pl. XX, fig. 2).

In the structure of the eye-spots and histology generally the New Zealand Planarian closely resembles *Bipalium* and *R. rhynchodemus.*

Observations on the living animal and fresh structures were made on two small living specimens of another species obtained at Wellington.

Strong cilia are present on the ventral surface of the body, as was seen by examining sections of the fresh animal in saliva and by applying the test of a small foreign body as in Geoplana; but cilia if present on the dorsal surface are very small and could not be detected either by direct observation or experiment.

Numerous rod-bodies were observed to be shot out of a fresh section just as in Geoplana, but the rod-cells were not isolated successfully. The rod-bodies, which are long and thread-like when shot, are well preserved in reagents and are to be seen in sections set up in Canada balsam, the epidermis being in some places covered with a felt of them.

Abundance of pigment of the same nature as that of Bipalium is present. Much of it often occurs deep in the tissues beneath the external systems of muscles (Pl. XX, fig. 8, p.)

The arrangement of the superficial muscles is peculiar, and differs from that in other Land Planarians, probably even from that existing in the American Geoplanas. A thin layer of circularly directed muscular fibres, the external circular muscular coat, is present as in Rhynchodemus and Bipalium, situate immediately beneath the epidermis, and beneath this lies a layer of longitudinal muscles disposed in a series of bundles of fibres homologous with the external longitudinal coat of Bipalium. This set of longitudinal muscles is very little developed on the dorsal region of the body, but excessively so over the whole ventral region or sole, as will be seen from Pl. XX, fig. 8. This set of muscles is developed nearly uniformly over the sole, and there is no indication of any specialisation of an ambulacral line.

The external longitudinal muscles are evidently in this Planarian the main muscles of locomotion, and take upon themselves a great part of the function which in Bipalium is performed by more deeply situate longitudinal fibres.

An enlarged view of the arrangement of the muscular fibres is given in Pl. XX, fig. 9, from which it will be seen that the bundles of external longitudinal fibres are separated by radiating fibres which pass outwards to join the external circular layer. A layer of internal transverse or circular fibres succeeds an interval occupied by radiating fibres only, and scattered over this are

to be seen in section numerous longitudinal fibres of the internal longitudinal set.

The arrangement corresponds very nearly with that occurring in Rhynchodemus ('Phil. Trans.,' l. c., Pl. XI, fig. 2), except in the extraordinary development of the external longitudinal muscular layer.

Embedded in the inner muscular structures is an abundance of a matter which appears to correspond to the glandular tissue of Bipalium, and like it stains very deeply with carmine. In the lower regions of the body it forms large ramifications.

In the region of the body lying around the sheath of the pharynx and that of the generative organs a glandular tissue is present in great quantity, filling the interstices between the deeper muscles (fig. 8, *g*).

The structure marked x in fig. 8 is evidently homologous with the spaces present in Bipalium sections, which were considered to represent the primitive vascular system with the nervous system probably lying in them ('Phil. Trans.,' l.c., Pl. X, fig. 5, *w*). As in Bipalium these structures in the present species stain very slightly with carmine. Instead of being confined to two circumscribed areas in a vertical section, however, as in Bipalium, or to two such areas connected by a transverse link, the structures here assume the form of an irregular band stretching across the entire width of the vertical sections.

I have been unable to examine these organs in longitudinal sections for want of sufficient material. I cannot come to any certain conclusion as to what they represent, but think it probable that they may represent a diffuse and ill-differentiated nervous system, since well-developed nervous structures such as occur in Marine Planarians, such as Eurylepta, are certainly wanting in all the genera of Land Planarians examined by me. The portions of the structures in question, situate in the region near the position of the oviducts (Pl. XX, fig. 8, *od*), agrees in histological construction closely with the homologous areas in Bipalium, showing a fine reticulation of fibres whilst their continuations on either hand show a fibrillation in the direction of the plane of the section, so that it would appear as if in the region of the oviduct bodies of fibres and canals having a longitudinal direction in the animal's body were cut across, and that these longitudinally directed cords or canals gave off transverse branches, which appear in the sections as the horizonal extension of these lightly stained areas. As already described, a similarly diffused nervous system or nervous system and primitive vascular system appears to exist in the S. American Geoplanas. In the present form it occupies a much wider space in the head of the animal, just as in Bipalium ('Phil. Trans.,' l.c., Pl. XIV, fig. 7),

but does not there give evidence of any more elaborate structure. I am uncertain as to the exact nature of this structure in the Land Planarians, and at a loss to explain how it is that these forms should not possess a nervous system at least as highly differentiated as that of Eurylepta.

The digestive system is essentially similar in structure to that in other Land Planarians. There is a single mesially placed main digestive tube in the front of the body which divides into two at the point of entrance into it of the pharynx and remains double to the hinder extremity of the body, the two tubes embracing between them the cavity of the pharynx and the sheath containing the mass of the generative organs (Pl. XX, fig. 3). The two tubes remain without communication with each other to the extremity of the body. The lateral diverticula are given off as in *Rhynchodemus*. Very short rudiments of diverticula are, however, present on the inner sides of the two posterior main digestive tubes which are not present in *Bipalium* or *Rhynchodemus*.

The arrangement of the openings of the diverticula into the main canals is shown in Pl. XX, fig. 6. The mouths of the diverticula appear as vertically directed, irregularly oval slits which are arranged in a line on the outer walls of the main canals and are of two sizes, smaller ones alternating with larger. A narrow longitudinally directed groove or depression connects the middle of the mouths of the diverticula with one another.

The pharynx is of the same simple cylindrical form as in Rhynchodemus, and is contained in a sheath or cavity just as in other land planarians.

The main mass of the generative organs is packed in an elongate cavity, with well-developed special walls situate just behind that containing the pharynx. Within this cavity the organs are further protected by a second investment of tough membrane which divides them up into four rounded masses disposed in a series or chain (Pl. XX, fig. 4, *a*, *b*, *c*, *d*.)

The organs consist of a bulbous vesicula seminalis situate most anteriorly in the elongate cavity, from which vesicula a tortuous and capacious ejaculatory duct leads to the large bulb of the penis. An accessory bulb or sac is present in connection with the penis and lower part of the male duct (Pl. XX, fig. 5, *x*), the exact relations of which to the penis were not determined.

The penis is protruded from the single generative aperture, and from this the vagina also opens, leading to the simple ovoid uterus which is situate most posteriorly in the cavity containing the generative organs.

In the four masses into which the generative organs are bound up by their immediately investing sheath the most posterior

mass consists of the uterus; the next contains the accessory bulb of the penis; the next the bulb of the penis itself and part of the ejaculatory duct; and the fourth or most anterior the vesicula seminalis and upper part of the duct.

There is a single pair of ovaries present, and these organs are situate at a distance from the anterior extremity of about one sixth the length of the body, on either side of the main digestive canal and close to the outside of its wall (Pl. XX, fig. 3, *o*). The oviducts spring from the outer sides of the ovarian sacs and pass directly down the length of the body to reach the uterus, maintaining a similar position in the deeper muscular structures to that which they hold in Bipalium and Rhynchodemus, as is seen in Pl. XX, fig. 8, *o*, *d*.

The testes consist of very numerous small ovoid bodies which are so dispersed as to form a band stretching from a point just posterior to the position of the ovaries to the level of the hinder end of the pharynx. A wide vas deferens, which is tortuous, as in Bipalium and Rhynchodemus, leads from the hinder end of the testes transversely inwards to the vesicula seminalis. The oviducts pass above the vas deferens in their course to the uterus.

Together with the two specimens of planarians Mr. Travers brought me preserved in the same spirit several of their egg capsules. These capsules were perfectly spherical and varied in diameter from 6 mm. to 4½ mm., being as large as an ordinary pea. Their walls were firm and resistant, and of a very dark brown or almost black colour. The walls are composed of a thin continuous sheet of a dark brown chitinous substance, which is highly elastic and rolls up into scrolls when torn into fragments. The brown substance shows no definite structure, but only fine granules partly scattered evenly through a homogeneous base, partly gathered into patches in it.

The egg capsules were found to contain from four to six embryos (Pl. XX, fig. 7), which lay quite free within the cavities of the capsules, and closely packed together, being curved up to accommodate themselves to the confinement. In one capsule the embryos were in a comparatively early stage. They were in form much wider in proportion to their length than the adults, and flatter, resembling more in form aquatic planarians.

In the more advanced stages the embryos were of nearly the same form as the parents, and had their oral apparatus already well developed. Each had further a pair of broad dark stripes on its dorsal surface, the stripes being disposed so as to leave a mesial light band between them. This colouring does not correspond with that of either of the adult species which I examined. It may change with advancing development, or the egg capsules may have

belonged to another species. The method of reproduction of the land planarians thus is closely similar to that obtaining in aquatic forms, such as *Dendrocælum lacteum*, and is such as it was conjectured that it would prove to be ('Phil. Trans.,' l. c., pp. 139, 141).

Australian Land Planarians.

I have been able to find no published description of these forms, for the reception of which I have made the new genus *Cœnoplana*. They are remarkable for their length, one species, *Cœnoplana subviridis*, attaining to a length of 17·5 cm., and in this respect they form a step towards the Manilla Dolichoplanas from the Geoplanas, which they resemble in the arrangement of the eyes. Their anatomy I have not yet worked out, but a few transverse sections made show that they closely resemble Rhynchodemus in the structure of their lateral organs, whilst in the arrangement of their muscles they are intermediate between Geoplana and Dolichoplana, from which latter they differ principally in having many small eye-spots instead of single pair of larger eyes.

The specimens procured were found in New South Wales, at Parramatta and at Camden Park. They were found during the day coiled up in cavities under fallen logs, and at night, observed with a lantern, crawling in the trunks of Eucalyptus trees, especially about wounds from which sap was exuding

The remarkable Prussian blue-coloured *Cœnoplana cærulea* has its intense pigment contained to a large extent in the rod-cells, which stand out thus in relief in the vertical sections of the animal. The blue colour changes to red when the pigment is acted on by acids, but the red colouring matter of *C. sanguinea* does not become blue, as might possibly have been expected, when acted on by alkalies.[1]

At Aru, Ke, and Amboina, land planarians were not found, though searched for carefully.

At Ternate one specimen of the form of a Ceylon Rhynchodemus was met with under the bark of a tree at an elevation of about 2000 feet. The planarian was of a bright yellow, with a single, median, narrow, dorsal, black stripe, extending the entire length of the animal. It was more lively than any land planarian which I have hitherto seen, wriggling out of a box or the hand with great quickness. The specimen, unfortunately, perished almost entirely from not having been placed in alcohol soon enough. Enough remained to show that it had a remarkable

[1] "On the Colouring Matters of Various Animals, and especially of Deep Sea Forms, dredged by H.M.S. Challenger." By H. N. Moseley, 'Quart. Journ. Micro. Science,' Vol. XVII, new ser., p. 1.

abundance of nematocysts, and that the mouth is simply elongate cylindrical, as in Rhynchodemus.

Its wriggling motion seems to point to the occurrence in it of greatly developed external longitudinal muscular bundles all over the body surface, as in Dolichoplana.

Land Planarian of Manilla—Dolichoplana striata.

I obtained three specimens of a land Planarian, for which I propose the above name, at Manilla, from a resident in the city. The Planarian is most remarkable for its great length and proportionately small breadth. The longest specimen of the three in the contracted condition in spirit was 19·5 cm. in length, and the shortest 12 mm.; while the average breadth of the specimens was only 3·5 mm., and the thickness 2 mm.

The Planarians are long, narrow, flattened and band-like, tapering rapidly to a blunt point at either end. The measurements of the three specimens, showing the position of the mouth and generative aperture, are as follows:

	a.	*b.*	*c.*
Anterior extremity to mouth. Distance	5·25 cm.	5·5	6·5
Mouth to generative aperture. Distance	5·5 "	6·1	4·7
Generative aperture to tail. Distance	9·25 "	5·5	4·7
Total lengths	20·0	17·1	15·9

The relative positions of the organs thus vary very much in the different specimens, probably because of unequal contraction due to the action of the spirit.

The bottle containing the specimens unfortunately got broken on board the ship in a gale of wind, and the specimens dried up, and are now unfit for anatomical examination; but some few sections had been prepared before the accident, and thus some facts as to the anatomy were determined.

Notwithstanding the extreme length of the body the ovaries are situate near its anterior extremity, as in Rhynchodemus, and hence the oviducts have to traverse an enormous distance in order to reach the uterus. They must be 9 or 10 cm. in length.

A single pair of eyes only is present, as in Rhynchodemus. These are placed laterally, close to the anterior extremity.

The genus is especially remarkable for the extraordinary development in it of the external longitudinal muscular layer which occurs all over the body, being especially marked in the dorsal region, as will be seen from Plate XX, fig. 25. The longitudinal muscular fibres form very compact well-defined bundles, which are conspicuous in transverse sections of the animals, and are separated from one another by stout radial muscular bundles. The

bundles of external longitudinal muscles are especially large in the lateral regions of the dorsal and ventral surfaces of the body. They are less fully developed at the actual lateral margins of the body and about the middle line of both dorsal and ventral surfaces. The bundles on the dorsal surface are more fully developed than those on the ventral, the exact reverse thus here occurring to the condition obtaining in the New Zealand land planarian, the arrangement being, however, very like that occurring in the Australian form of the group.

A broad, pale band on the ventral surface of the animals seems to represent an ambulacral line, but I have not found special internal muscular structures corresponding with it. Possibly the band is due to the presence of long cilia. In a transverse section of the body a zone occupied only by radial muscular fibres, succeeds the layer of external longitudinal muscles internally. Within this zone, in the ventral region of the body, is a mass of internal longitudinal muscular fibres, irregularly disposed (Plate XX, fig. 25, *ilm*); at the ventral edge of which mass is a row of specialised bundles of longitudinal fibres, resembling those of the external longitudinal layer (fig. 22, *a*). This row of bundles extends to beyond the region of the ovary on either side. Some transversely directed fibres intervene between the row and the external longitudinal bundles in the region of the ambulacral line (fig. 25, *b*). There seem to be hardly any longitudinal muscles developed in the dorsal region of the body besides those of the external layer.

Strong bands of transversely directed muscles pass across the body immediately above and below the digestive cavities, strengthening their floors and roof (fig. 25, *trm*). These transverse fibres, which must be regarded as representing the internal circular muscular system, lap round the outer ends of the diverticula with a few of their fibres, as seen in fig. 25. Strong vertical fibres pass on either side of the main digestive canals and traverse the interspaces between the internal longitudinal muscles to join the radial fibres, with which they are continuous, in the dorsal and ventral regions of the body.

The lateral organs (Plate XX, fig. 25, *x*) are very like those of Rhynchodemus in structure. The position of the oviduct with regard to them is the same as in all other Land Planarians; as is also that of the testis.

The digestive diverticula were observed to ramify very freely in the fore part of the body, apparently to a greater extent than they do in Rhynchodemus.

Land Planarians of South Africa.

Two species of Land Planarians were obtained at the Cape of Good Hope, a region from which they had been supposed to be absent, Grube having laid stress on their absence from Africa, and consequently supposed correspondence in distribution with the land leeches.[1]

The Planarians were found in the grounds of the Astronomical Observatory at Wynberg, Cape of Good Hope.

Sections of the fresh tissues were examined. When a vertical section was pressed slightly under a covering glass, elongate, rod-like bodies were shot out from the surface of the skin, and seen to project from it in great numbers. Amongst the rods also were seen masses of slime ejected by the slime glands, which I have described as existing in the Rhynchodemus and Bipalium ('Phil. Trans.,' l.c., p. 121), and which I here observed in action (Pl. XX, fig. 24). The long rods (Pl. XX, fig. 23) are contained, when quiescent, within ovoid transparent cells, in which they are coiled up in an irregularly spiral manner.

Three or four rods are present in each cell, and the rods are shot clear of the cell when it ruptures and ejects them. There is hence no further point of resemblance here brought out between the rod-cell and the nematocysts of Cœlenterates (Pl. XX, figs. 19 and 20). The ends of the rods when free show a tendency to bend over and curl up. Rod-cells also occur in these species of Rhynchodemus, as in all aquatic Planarians in which the rods are short and straight, and not twisted spirally.

Diagnosis of two new genera and nine new species of Land Planarians.

Genus Geoplana.

1. *Geoplana flava*, sp. n. (Pl. XX, fig. 10).—Body elongate, flat beneath, only slightly convex above, attenuate at both extremities, the anterior terminating bluntly. Body of a clear light yellow colour on the dorsal surface, shading into burnt sienna colour at the two extremities and the lateral margins. A glistening white stripe passes along the entire length of the back along the middle line, reaching to the tip of the head. Four narrower similar stripes are present on either side of the mesially placed one, and extend along the body parallel to it. Eye-spots are present in two elongate, irregular patches, one on either side, near the anterior extremity, and scattered sparsely on the lateral margins for the entire length of the animal.

[1] Ed. Grube, 'Ueber Land-Planarien, Jahresbericht der schlesischen Gesells. für Vaterländ. Kultur,' 1866, p. 61.

Under surface pale yellowish. Length, 3 cm.; breadth, 5 mm. Mouth at about the centre of the under surface.

Bahia, Brazil.

2. *Geoplana Traversii*, sp. n.—Body elongate, flat beneath, slightly convex above, bluntly pointed posteriorly, more gradually attenuated anteriorly; broadest in the centre. Mouth central in position. Generative aperture situate at little less than half the distance between the mouth and posterior extremity. Ambulacral line absent, the whole under surface acting as a sole.

Eye-spots forming a single row of ten or so on the front of the anterior extremity, and an elongate patch composed of two or three rows on the lateral margin of the body, just behind the anterior extremity; also present, sparsely scattered, on the lateral margins of the body for its entire length.

Body of a pale yellow on the lateral margins, with a broad mesial stripe on the dorsal surface, extending for its entire length, of a dark chocolate colour, and four narrow, ill-defined, and somewhat irregular similarly coloured stripes on either side of it, extending to the lateral margins of the body. Under surface pale yellow.

Length of largest specimen contracted in spirits, 3 cm.; extreme breadth of same, 8 mm.; length of pharynx of same, 3·5 mm.

N.B.—The above description applies to two specimens received at Wellington from Mr. Locke Travers, in spirits.

Two other specimens, obtained from him at the same time, also in spirit, agree with the above description in all respects, excepting that they have, curiously enough, a pair of well-defined, dark, longitudinal stripes, on the under surface of the body.

Further, two living specimens of a Geoplana were obtained at Wellington by collectors from the 'Challenger,' which were each 2·5 cm. in length. They were of a fine rich yellow colour along the sides, with a broad mesial longitudinal stripe of very dark chocolate on the back, which was seen by the aid of a lens to consist of reticularly arranged pigment, denser along a narrow median line towards the head and at the verges of the broad band. The under surfaces were pale yellow with reticulations of pale brick-red pigment. These latter may have been the young of *G. Traversii*, and the specimens with striped soles varieties of the same. Or two further species may be here represented. The egg capsules obtained seem to have been certainly of a distinct species from *G. Traversii*, since the embryos contained in them have a light mesial dorsal stripe bounded by dark stripes on either side. It is hoped that some resident New Zealand naturalist may investigate the species of Land Planarians of the island.

Genus Cænoplana—Gen. nov., Moseley.

Body long and wormlike, much rounded on the back, flattened on the under surface, without an ambulacral line. External longitudinal muscular bundles largely and evenly developed over both dorsal and ventral regions. Lateral organs distinct and isolated as in Rhynchodemus, and, as in it, connected by a transverse commissure. Eyes absent from the front of the anterior extremity, but present in two lateral elongate crowded patches placed just behind the anterior extremity and scattered sparsely on the lateral margins of the body for its entire extent.

Mouth nearly central, pharynx cylindrical.

Habitat.—New S. Wales.

1. *Cænoplana cærulea*, sp. n., Moseley. Entire body of a dark Prussian blue colour, somewhat lighter on the under surface of the body and with a single, narrow, mesial, dorsal, longitudinal stripe of white. Length 5 cm., extreme breadth 4 mm., mouth central; generative aperture 8 mm., posterior to the mouth. Parramatta, near Sydney. Under the bark of a species of Eucalyptus.

2. *Cænoplana sanguinea*, sp. n., Moseley.—Closely resembles C. Cœrulea, with the exception that it is coloured of a uniform light red, which is lighter upon the under surface of the body. Actual length when living 7 cm.; breadth 4 mm. Parramatta, near Sydney. Amongst earth at the roots of a Eucalyptus stump.

3. *Cænoplana subviridis.*—Ground colour of the body greenish yellow beneath. In the mesial line of the dorsal surface is a broad band of the ground colour, bordered on either side by a somewhat narrower but very sharply defined intensely black band. Beyond the black bands externally on either hand lie bands of the ground colour of equal breadth to them; and beyond these again is a very broad band which extends outwards nearly to the lateral margin of the body, which band is composed of a shading of fine longitudinal streaks of reddish brown, and is bordered on either side by a narrow dark, nearly black, margin, the inner border being more intensely pigmented of the two. The bands and lines become narrower and more indistinct towards ths posterior extremity, and eventually blend. The immediate anterior extremity of the animal is of a bright burnt sienna colour, darker towards the tip. Length of largest specimen when living and crawling 16 cm.; breadth 4 mm.; length of smaller specimen when crawling 12·5 cm. Camden and Parramatta, N. S. Wales. Under dead logs and on bark of Eucalyptus trees.

Genus Dolichoplana, gen. nov., Moseley.

Body extremely long and narrow, flattened, and band-like-tapering to a blunt point at either extremity. Mouth situate at a distance from the anterior extremity of about one third the length of the body. Generative aperture at about the same distance posterior to it. Eyes two only, as in Rhynchodemus. External longitudinal muscular bundles very much developed all over the body, but especially in the dorsal regions, where they are the only longitudinal muscles present. Ambulacral line slightly indicated. Lateral organs as in Rhynchodemus.

Habitat.—Philippine Islands.

Dolichoplana striata, sp. n., Moseley. Body of a light olive-brown colour, with two narrow black longitudinal stripes on the dorsal surface. The pair of bands nearest the middle line are sharply defined and are separated from one another by a broad mesial band of the ground colour of the animal.

The outer pair of bands is less distinctly defined. The bands are placed on the lateral margins of the body and are separated by wide intervals from the inner pair.

Three spirit specimens varied in length between 19·5 cm. and 15·9 cm., and in breadth measured about 3·5 mm.

Three specimens only, found in the neighbourhood of Manilla, were obtained in spirit from a resident in that city.

Genus Rhynchodemus, Leidy.

1. *Rhynchodemus flavus*, sp. n. Moseley (Pl. XX, fig. 20).—Body of the usual form but much attenuated anteriorly, of a uniform light yellow colour, with a narrow jet black, wavy mesially placed dorsal line. Length about 4 cm. The Observatory Grounds, Cape of Good Hope.

2. *Rhynchodemus fuscus*, sp. n., Moseley (Pl. XX, fig. 19).—Body rather blunt-ended anteriorly, of a flesh colour, with a pair of broad bands of mottled brown placed on the dorsal surface so as to leave between them a narrow mesial light stripe, with a light patch at the anterior extremity. The bands do not extend quite to the lateral margins of the body. Length, about 1·5 cm. The Observatory Grounds, Cape of Good Hope.

Genus Bipalium, Stimpson.

Bipalium unicolor, sp. n., Moseley. Body of the usual form, but with the semilunate anterior expansion of moderate development only. The entire body of a uniform orange-yellow colour, lighter on the ventral surface. The anterior margin of the semilunate expansion dark, almost black. Length of spirit specimen, 6·5 cm. Greatest breadth, 7 mm.

Zamboangan Mindonao Philippines.

Catalogue of the species of Land Planarians at present known.

Group.—MONOGONOPORA, Stimpson.

Family.—LEIMACOPSIDÆ, Diesing.

Genus Leimacopsis.—Diesing, Revision der Turbellarien, Abtheilung Dendrocœlen, Sitzbt. Akad. Wiss., Wien, 1861, p. 488.

Leimacopsis terricola.—Diesing, l. c.
Prostheraceus terricola.—Schmarda, 'Neue Wirbellose Thiere,' Th. 1, 1—30, Tab. VI, fig. 69.
With a pair of true frontal tentacles beset with numerous eyes. Occurs high up in the Andes at the pass of Quindiu, above the region of mountain palms.

Family Geoplanidæ.

Genus Polycladus.—Blanchard, Historia Fisica y Politica de Chile por Claudio Gay, Fauna Tomo tercero.' Paris, 1854, p. 6.

1. *Polycladus Gayi.*—Chile. Blanchard, l.c. Pl. Annilados, No. 3.
The body is much flattened. Blanchard gives some details of anatomy, but he mistook the head for the tail of the animal. The generative organs are situate further from the mouth than in Geoplana N. Zealandiæ. It is possible that this genus of the Western side of the Andes may prove a natural and distinct one.
2. *Polycladus Andicola.* — Schmarda, 'Neue Wirbellose Thiere,' 1, 1—15, Tab. II, 31 and 31 *a.*
Schmarda refers this Andean species to the genus. The body is flat and oblong. He is evidently in error in speaking of two generative apertures as present in front of the middle of the body.

Genus Geoplana (Stimpson and Max Schultze). Stimpson, Prodromus descriptionis animalium evertebratorum quæ in expeditione ad Oceanum Pacificum Septentrionalem, &c. Pt. 1, Turbellaria Dendrocœla, Proc. Acad. Philad., 1857, p. 19.
Max Schultze, Beiträge zur Kenntiss der Land-Planarien nach Mittheilungen des Dr. Fritz Müller, in Brasilien und nach eigenen Untersuchungen, Halle Abdhn., 1856, p. 20.

1. *Geoplana vaginuloides.*—Rio Janeiro. Darwin, 'Ann. and Mag. Nat. Hist., vol. xiv, 1844, p. 241 = *G. elegans,* Brazil, Fritz Müller and Max Schultze, l.c.

2. *Geoplana elegans.*—Rio Janeiro. Darwin, l.c.

3. *Geoplana pulla.*—Montevideo and Maldonado. Darwin, l.c. = G. [illegible]? or G. Maximiliana? Brazil, Fritz Müller and Max Schultze, l.c.

4. *Geoplana bilinearis.*—Montevideo and Maldonado. Darwin, l.c.

5. *Geoplana nigrofusca.*—Montevideo and Maldonado. Darwin, l.c.

6. *Geoplana pallida.*—Valparaiso. Darwin, l.c.

7. *Geoplana tristriata.*—Brazil. Fritz Muller and Max Schultze, l.c.

8. *Geoplana schistriata.*—Brazil. Fritz Muller and Max Schultze, l.c.

9. *Geoplana Schultzei.*—Brazil. Diesing, l.c. = *G. pallida*, Fritz Müller and Max Schultze, l.c. (not *Planaria pallida* of Darwin).

10. *Geoplana atra.*—Brazil. Fritz Müller and Max Schultze, l.c.

11. *Geoplana Mülleri.*—Brazil. Diesing, l. c. = G. elegans, Fritz Müller and Max Schultze, l. c. (not *Planaria elegans* of Darwin).

12. *Geoplana marginata.*—Brazil. Fritz Müller and Max Schultze, l. c.

13. *Geoplana rufiventris.*—Brazil. Fritz Müller and Max Schultze, l. c.

14. *Geoplana olivacea.*—Brazil. Fritz Müller and Max Schultze, l. c.

15. *Geoplana nephelis.*—Brazil. Fritz Müller and Max Schultze, l. c.

16. *Geoplana Maximiliani.*—Brazil. Fritz Müller and Max Schultze, l. c. (= G. pulla, Darwin?).

17. *Geoplana marmorata.*—Brazil. Fritz Müller and Max Schultze, l. c.

18. *Geoplana pulchella.*—Brazil. Fritz Müller and Max Schultze, l. c.

19. *Geoplana Burmeisteri.*—Rio Janeiro. Max Schultze, [illegible]

20. *Geoplana flava.*—Bahia, sp. n., Moseley [illegible]

21. *Geoplana Traversii.*—Wellington, New [illegible] Moseley.

22. *Geoplana elongata.*—[illegible]

23. *Geoplana* [illegible] C. Tres Montes. Darwin [illegible]

24. *Geoplana* [illegible] *Nob.*—[illegible] Hambard? [illegible] it seems [illegible]

25. *Geoplana lapidicola*.—Island of Loo Choo. Stimpson, l. c.

With eyes few in number, scattered on the margins of the head and three or four larger ones on either side on the frontal margin. This will possibly prove allied rather to *Rhynchodemus*.

26. *Geoplana Tasmaniana*.—Tasmania. Darwin, l. c. This will possibly prove allied to the Australian genus *Cœnoplana*.

Genus.—*Geobia*, Diesing, l. c.

Geobia subterranea.—Brazil. Diesing, l. c., *Geoplana subterranea*, Fritz Müller and Max Schultze, l. c.

Long and narrow, with rounded extremities, eyeless, and colourless. Lives under ground in the holes of *Lumbricus corethrurus*, and preys upon that annelid.

Genus.—*Cœnoplana*, gen. nov. Moseley.

1. *Cœnoplana cœrulea*.—Parramatta, N.S. Wales, sp. n. Moseley.
2. *Cœnoplana sanguinea*. Parramatta, sp. n. Moseley.
3. *Cœnoplana subviridis*.—Parramatta. sp. n. Moseley.
4. *Cœnoplana ?* sp. ?—Ternate Moluccas. Moseley.

Genus.—*Dolichoplana*, gen. nov. Moseley.

Dolichoplana striata.—Manilla, sp. n. Moseley.

Genus.—*Rhynchodemus*, Leidy, Proc. Acad. Nat. Sci. Philad., vol. v, 1851.

1. *Rhynchodemus terrestris*.—Europe, O. F. Müller and others.
2. *Rhynchodemus sylvaticus*.—N. America, Leidy, l. c.
3. *Rhynchodemus bistriatus*.—Samoan Islands, Grube. 'Novara, Exp. Zoologischer Theil.,' Bd. ii, "Anneliden," p. 45.
4. *Rhynchodemus quadristriatus*.—Samoan Islands, Grube, l. c.
5. *Rhynchodemus Nietneri*.—Ceylon, Humbert, Mém. Soc. Phys. Genève, 1861, p. 306.
6. *Rhynchodemus Thwaitesii*.—Ceylon, Moseley, Phil. Trans. R. Soc., 1874, p. 107.
7. *Rhynchodemus flavus*.—Cape of Good Hope. Moseley, l. c.
8. *Rhyncodemus fuscus*. Cape of Good Hope. Moseley, l. c.
9. *Rhynchodemus Tannayi*. Brazil. Ferussac, Ann. Gen. Sci. Phys., t. viii, 1821, pp. 90-92, tab. cxvi, 2 et 3.

It seems probable that this will prove to differ in structure from the Indian and Cape forms.

10. *Rhynchodemus* (*Geodesmus*) *bilineatus*. Mecznikow, Bull. Acad. St. Petersburg, 1865, vol. ix, p. 433.

There is no certainty as to how far the above genus is a natural one. The anatomical structure of the Ceylon and Cape species and of *R. bilineatus* only is known, and it seems doubtful whether the latter of these should be referred to the same genus as the former, its generative organs not having been sufficiently determined.

Genus.—Bipalium. Stimpson, Silliman's Journal of Science, May, 1861, second ser., xxxi, p. 134.

1. *Bipalium Phœbe.* Ceylon. Humbert, l. c.
2. *Bipalium Diana.* Ceylon. Humbert, l. c.
3. *Bipalium Proserpina.* Ceylon. Humbert, l. c.
4. *Bipalium Ceres.* Ceylon. Moseley, Phil. Trans. Roy. Soc., l. c.
5. *Bipalium Dendrophilum.* Ceylon. Schmarda, l. c., p. 36.
6. *Bipalium lunatum.* Bengal. Gray, Zool. Misc., p. 5, 1835, cit. Silliman's Journ., 1861, p. 135.
7. *Bipalium Ferudporense.* Bengal. Wright, Ann. and Mag. Nat. Hist., 1860, vi, p. 54.
8. *Bipalium Cantori.* China. *Dunlopea Cantoria,* Wright, l. c. Chinese Repository, Canton, 1832 *et seq.*, vol. x, p. 434; Calcutta Journal of Nat. Hist., No. 5, p. 436.
9. *Bipalium Grayi.* Chusan. Cantor, Ann. and Mag. Nat. Hist., 1842, ix, p. 277; *Dunlopea Grayia,* Wright, l. c.
10. *Bipalium Stimpsoni.* China, Hong Kong. Diesing, l. c.; Stimpson, Prodromus Animalium, &c.; Proc. Acad. Philad., 1857, pp. 30, 31.
11. *Bipalium virgatum.* Loo Choo. Stimpson, l. c.
12. *Bipalium maculatum Ousimon.* Stimpson, l. c.
13. *Bipalium fuscatum.* S modu. Stimpson, l. c.
14. *Bipalium trilineatum.* Jesso. Stimpson, l. c.
15. *Bipalium univittatum.* Madras. Grube. Novara. Exped. Zoologischer Theil, Bd. ii, p. 45.
16. *Bipalium Everetti.* Borneo. Rev. W. Houghton, Ann. and Mag. Nat. Hist., 1870, p. 255.
17. *Bipalium Houghtoni.* Borneo. Houghton, l. c.
18. *Bipalium unicolor.* Zamboangan Mindonao Philippines, sp. n., Moseley.
19. *Bipalium,* sp.? New Zealand. Hutton, l. c.

Summary.

The results of the present paper may be briefly summarised thus:

Land Planarians are now known to exist in nearly all temperate

and tropical regions, and probably exist in all. They may be placed in two families:

(*a*) Leimacopsidæ, with eye-bearing frontal tentacles. 1 genus. 1 species at present known.

(*b*) Geoplanidæ. Without tentacles. 7 genera. 62 species.

The structure of Leimacopsis is not known, but it seems probable that it may differ very much from that of the Geoplanidæ.

Of the Geoplanidæ, the complete anatomy, including that of the generative organs, is known as yet only in the case of certain species of Rhynchodemus, and Bipalium from Ceylon, and in *Geoplana Traversii* of New Zealand. The arrangement of the muscles and of the lateral organs (nervous systems, or primitive vascular systems?) of the Rhynchodemus of the Cape of a Geoplana of Brazil, of the Australian Cœnoplanas, and Manilla Dolichoplanas, has been determined, and it appears that the Geoplanidæ form a very natural family, although it remains to be seen how far the European forms at present placed in the genus Rhynchodemus conform to the type. In all the Geoplanidæ the external sets of circular and longitudinal muscles are more fully developed than in the aquatic species in conformity with the requirements of motion on land. In Geoplana and the Australian genus this condition is more marked than in Rhynchodemus and Bipalium, and is carried to excess as far as the longitudinal bundles are concerned in Dolichoplana, in which form locomotion is probably principally muscular and annelid-like. In all the Geoplanidæ further the generative organs show a tendency to specialisation higher than that of most aquatic forms. In *Geoplana Rhynchodemus* and Bipalium, and in Polycladus, as appears from Blanchard's figures (Blanchard, Hist. de Chile, l. c.), the ovaries are reduced to small simple piriform sacs, which are placed near the anterior extremity of the body, and have long simple oviducts leading for more than half the length of the body to the uterus. This condition is conformed to even in the enormously long Dolichoplana. The intermittent organs and reservoirs are closely similar in all the genera examined. The Geoplanidæ are all monogonoporous. In all the uterus is simple and situate just posteriorly to the penis. The highest specialisation of the generative organs appears to occur in Bipalium. In the concentration of these organs and special development of the muscular systems the Geoplanidæ seem to form a step from the aquatic forms towards the leeches.

From the facts of anatomy, at present ascertained, it appears that the New Zealand forms are most closely allied to the S. American, whilst the Cape species are related to the Indian land planarians—a conclusion which is borne out by other facts of distribution of species. The Australian Cœnoplanas form a step

between the Geoplanas and the Dolichoplanas of Manilla. The occurrence of Bipalium in New Zealand seems a very remarkable fact, and it is hoped that the species will be carefully described.

The curious rod-cells of land planarians are remarkable structures. Several long hyaline rods occur coiled up together in each cell, and these rods are shot forth on irritation of the animal. The rods are, however, unconnected with the cell-wall, and their structure does not afford further evidence of relationship between rod-cells and nematocysts. It would be interesting to test the surface of a living land planarian with the tongue and ascertain whether any sensation of urtication is produced. The rod-cells of *Rhynchodemus bilineatus* are very similar to those of other land planarians, but the long rods seem to differ in that case in being tapered at either end.

The discovery of the mode of reproduction of land planarians is of much interest. The chitinous capsule containing several ova, and eventually embryos, which are entirely free in its cavity, is closely similar to that of, *e. g.*, *Dendrocœlum lacteum*, but necessarily much larger. No metamorphosis appears to occur in the progress of development.

NOTES AND MEMORANDA.

Pithophoraceæ—a new Order of Algæ.—One of the most important and interesting of recent memoirs contributing to our knowledge of the Algæ is that by Dr. Veit Brecher Wittrock, of the University of Upsala, "On the Development and Systematic Arrangement of the Pithophoraceæ, a new Order of Algæ," ('Nova Acta Reg. Soc. Sc. Upsal.,' 1877). This new Order belongs to Chlorophyllophyceæ, and as yet contains but a single genus Pithophora, Wittr., made up of eight (as yet known) species (with a probable ninth, already partially known to the author).

As the work is throughout written in English it is the more unnecessary to attempt to give a *résumé* at any length, though not out of place to draw the attention of our readers thereto in this brief summary. The species belonging to Pithophora, in habit and appearance, very much resemble forms of Cladophora; in fact, some of them had already been referred by previous algologists to that genus, from which, however, Wittrock shows his new genus to differ strongly.

The author's first acquaintance with a Pithophora-species was made at the Royal Gardens, Kew, and the plant was collected by him in the Tropical Aquarium or Water-lily House; he names the species there found *P. Kewensis*. As the other species known to him emanate from tropical or subtropical regions he concludes that *P. Kewensis* had been introduced from a tropical country, probably South America. In those regions the species known belong to freshwater, none to salt, whilst one was found on humid earth.

The order is thus characterised:—Chlorophylliferous Cladophora-like freshwater algæ, consisting of cells, formed by bipartition of the terminal cell. The thallus having two distinct parts, viz. 1, the cauloïd part, developed from the germinated spore upwards, propagative and almost always branched, the branches placed a little way below the top of their supporting cells; 2, the (morphologically, not physiologically) rhizoïd part, developed from the germinated spore downwards, almost always sterile and branchless, commonly

unicellular. Spores neutral, quiescent (agamo-hypnospores), generally cask-shaped, single, formed by division into two of the cauloïd cells, of the chlorophyll-filled and commonly widened upper parts of these cells; in germinating, as a rule, dividing into two cells, the one giving rise to the cauloïd and the other to the rhizoïd part of the thallus.

The character of the single genus is of course the same as the order. The author divides the genus into two sections; 1. Pithophoræ isosporeæ, in which the spores are all of the same principal form in each species—the enclosed (interstitial) cylindrical or cask-shaped, the terminal with the upper end conical and the top somewhat rounded (5 species); and, 2. Pithophoræ heterosporeæ, in which the spores are of several, dissimilar forms in each species, the enclosed (interstitial) of three forms, viz., cask-shaped, cylindrical and sub-irregular, the terminal as a rule of two forms, viz., cask-shaped and cylindrical, but with the upper end conical and the top somewhat rounded (2 species).

Although, then, the character of the place of origin of the branches in Pithophoræ, as compared to Cladophoræ, being set some distance from, not at, the top of the cells or joints whence they emanate, may appear at first sight but trivial, it yet seems to carry with it further differences of a more important nature, that is to say, in the mode of spore-formation. The vegetative joints, as further differing from Cladophora, are also described as possessing a thin non-laminated membrane, and the cells are lined by a protoplasmic stratum having numerous chlorophyll-granules imbedded and enclosing a great cylindrical "vacuole." In fertile specimens, always of full size, colourless cells, that is, nearly or wholly destitute of chlorophyll, are to be seen besides the green ones. The formation of the spore is begun in a joint by its upper part widening into the characteristic nearly always more or less cask-shape, on the completion of which the chlorophyll contents of the lower portion pass up thereinto, the cavity becoming densely packed, whereupon a septum is formed cutting the mother-cell into two daughter-cells—one, the upper, being the spore, the other, the lower, being the already mentioned now colourless subsporal cell. The membrane of the spore now becomes considerably thickened; the contents often becoming brownish. In the principal filaments and sometimes in the branches of *P. Zelleri* (v. Mart.) Wittr., the whole of the contents of the subsporal cell often do not pass up but become formed into a spore below the other, thus forming twin-spores. This may accidentally also occur in other species. As if abnormally, again, the ordinary pro-

cess may be reversed occasionally and the contents of the upper part pass down and form a spore below. The order of the formation of the spores is usually basipetal. Quite exceptionally spores may be formed in the rhizoïd; when such takes place the spore is formed not in the upper but in the lower part of the mother-cell.

Besides spores so formed the author describes another kind of reproductive cells which he denominates "prolific cells." Certain ordinary interstitial (never terminal) joints, without any passing thereinto of chlorophyll, become, simply by absorption and storing up of nutriment, densely packed with chlorophyll-contents and starch-granules.

The germination of the spore, on becoming free by the dissolution of the adjacent cells, takes place by its pushing out, from each opposite end, a conically-cylindrical process, whereupon it becomes divided, usually about the middle, by a transverse or slightly oblique septum, one of the daughter-cells so formed giving origin to the rhizoïd, the other to the cauloïd; the transverse wall thus forming a sharp limit between these two parts of the thallus. It would take too much space to try to even condense the author's enlarged details as regards certain exceptional modes of germination, or on the method of ramification.

As to the germination of the prolific cells set free by dissolution of the rest of the plant, it takes place in the same manner as the formation of branches from ordinary cauloïd cells; that is, the new growth appears as a normal branch just below, that is, a short distance from, the top of the prolific cell.

The plant is most frequently not at all attached, and when it is occasionally so it is not by the rhizoïd, but by means of peculiar tendril-like organs developed from the cauloïd (mostly from the terminal cell) called by the author *helicoïds*. These are common only in one species, rare in others. They are sometimes almost straight, often curved, but most frequently quite claw-like and they grasp, like a tendril, around adjoining objects or their own branches. They are densely filled with chlorophyll-contents.

Looking at the vegetative growth in Pithophoraceæ their affinity to Cladophoreæ is apparent. So great is the resemblance that the author sometimes found no small difficulty in determining whether a sterile specimen really belonged to Cladophora or to Pithophora; as has been mentioned, the branches in the latter are given off a short distance from the top of the supporting cell and the joints are also habitually very long, but the great distinction is in the ("tap-root-"

like, but in no sense to be considered as functionally or physiologically a *root*) rhizoïd system. The author points out, touching the dependent ramifications called "rhizines" in *Cladophora fracta*, that the spore (here a zoospore) sends down in germinating one or two irregular processes, the rhizines, but with no formation of a septum; they are not shut off therefore as independent cells. Certain Cladophoreæ send down from other parts of the plant adventitious rhizines —others offer helicoïds on terminal cells. The essential difference then lies in the nature of the rhizoïd organs, formed immediately on germination of the spore, which seems to be correlated with the different nature of the spores, that is, hypnospores in one and zoospores in the other.

The author points out that, leaving aside vegetative characters and keeping in view only the mode of spore-formation, there is a resemblance to the *motionless* spores formed asexually (as indeed are the zoospores) in *Vaucheria geminata* (Vauch.), Walz, and *V. hamata* (Vauch.) Walz. But, as he further points out at some length, the differences are vastly more numerous and important than the resemblances, and Vaucheriaceæ, apart from the vegetative characters, may be dismissed as having any very near relationship to the Pithophoraceæ. Nor does there early appear any further group showing any near affinity to this order.

Reverting however, to the mode of spore-formation the author again refers to Cladophoreæ, not indeed to the zoospore-formation in the latter, but to those propagative cells found in Cladophora, most strongly evinced by *Cladophora fracta*. In that form those swollen pear-shaped densely filled joints seem actually to be formed similarly to the mode described for the hypnospores of Pithophora, that is, by the expansion of the upper portion of a joint, the lower retaining its original cylindrical figure, and far less densely filled with contents. Now, if a transverse septum were formed just below the widened part, we should have two cells, the upper of which would be perfectly homologous with the spore, as described, of Pithophora, the lower with the subsporal cell. If, further, the formation of zoospores were suspended, the Cladophora, as the author remarks, would be transformed almost into a perfect Pithophora. The author has seen, in *Pithophora œdogonia*, the true spores, formed in the normal manner, instead of germinating in the usual way and (apparently still *in sitû* on the plant), develop a branch laterally, quite in the same manner as prolific cells in Cladophoreæ. Therefore the author holds Pithophoraceæ are to be regarded as "transformed Cladophoreæ, thus being one

of the branches on the stem of Confervaceæ." The author adds a hypothetical "genealogical tree" of the Chlorophyllphyceæ, with some brief remarks on the Cohn-Sachsian principles of classification, adding that "a more particular account of the motives of this attempt it is his intention to publish on another occasion," a promise which algologists will be anxious he may early fulfil.

The author concludes his extensive and valuable memoir with complete and thorough descriptions of the species belonging to his new genus Pithophora, to which are appended six plates (uncoloured) pourtraying the characters of their habit and growth, so that the whole amounts to an exhaustive Monograph of the new Order.

On some Changes which Red blood-Corpuscles undergo in Extravasations. By Professor A. Bœttcher, in Dorpat.[1]—Referring to the observations of Dr. Max Knies on certain peculiar nucleated forms of blood-corpuscles found in blood twenty-four to seventy-two hours after having been injected into the anterior chamber of the eye of rabbit, Professor Bœttcher draws attention in this paper—of which only the first part will be here reported on—to observations of his own on a similar subject in 'Virchow's Archiv,' vols. 36 and 39, when he found that treating red blood-corpuscles with blood-serum or humour aqueus nucleated blood-corpuscles are to be met with.

Professor Bœttcher then describes another method, by means of which the nuclei of red blood-corpuscles of man and several mammalian animals may be readily demonstrated. Twenty-four to forty-eight hours after injection of defibrinated blood into the anterior chamber of the eye of rabbit, there were no distinctly nucleated red blood-corpuscles to be seen yet. But leaving this blood, viz., withdrawn after twenty-four hours, to stand in humour aqueus in a small glass for another twenty-four hours, the most splendid and diversely nucleated red blood-corpuscles could be demonstrated. The nucleus appears of different sizes, generally it is very sharply outlined; the larger nuclei are granular, the smaller pale. There are also few nuclei to be met with which had escaped their red corpuscles. There exists a difference between the red blood-corpuscles of man and rabbit on the one hand, and those of cat on the other, those of the former possessing a granular, those of the latter a pale nucleus, which at the same time can be recognised only under a higher power. Besides this the clear nucleus of many red blood-corpuscles of cat contains a nucleolus. If

[1] Virchow's 'Archiv,' vol. 69, part ii, p. 295.

cat's blood be treated with acetic acid after the colouring matter has been dissolved, the shining nucleoli may be still recognised.

On the Structure of the Human Peritoneum Diaphragmaticum. By Professor G. Bizzozero, in Turin.[1] Bizzozero having found a delicate membrana limitans underneath the endothelium of the human serous membrane, examined specially that membrane in the human peritoneum covering the diaphragm. The limitans of this latter can be easily isolated in fresh specimens as well as in those that had been treated with Müller's fluid. Bizzozero finds that the limitans in question, while at some places a continuous uninterrupted membrane, possesses at others numerous round or oval holes, which appear either irregularly scattered or grouped into larger or smaller groups. These latter consist of ten, thirty to sixty holes, measuring from 4, 10, to 16 mm. "This arrangement of the limitans stands in an important relation to the distribution of the lymphatics of the peritoneum diaphragmaticum. The lumen of the superficial lymphatics is not everywhere separated from the peritoneal cavity by an uninterrupted connective-tissue membrane, but on larger portions only by a connective-tissue meshwork. Over this the limitans is expanded in such a manner that its holes coincide with the holes of that meshwork. In this manner, if we exclude the surface endothelium, an open communication is established between the lymphatic vessels and the peritoneal cavity."[1] This relation is best developed on a part of the peritoneum which covers the muscles immediately around the central tendon. "The network of lymphatic vessels is here not so dense as on the central tendon, but the individual vessels are much broader, so that the membrane (especially in young individuals) appears cribrous already on the naked-eye inspection.

Publication of a series of Diatoms and of other Algæ. By Professor P. T. Cleve, of Upsala, Sweden, assisted by Mr. J. D. Möller, of Wedel, has the intention of publishing a series of mounted diatoms, marine and freshwater forms. The first part contains forty-eight slides, and its price is 40 shillings (40 Reichsmark, 50 francs), expenses of freight not included. Orders are executed from the middle of August this year, and may be sent to Professor Cleve. Many of our readers will also be glad to learn that Dr. Oeit B. Wittroch,

[1] Vienna Medic. Jahrbucher I., 1877.

A further communication on this subject by Bizzonzer and Salvioli ('Studi sulla struttura a sui linfatici delle sierose umane.' Parte prima.) will be reported upon in our next number.

[redacted]

of Upsala, and Herr Otto Nowstedt, of Lund, Sweden, announce the publication of a series of prepared algæ, chiefly freshwater, under the title "Algæ aquæ dulcis exsiccatæ, præcipue Scandinavicæ, adjectis algis marinis chlorophyllaceis et phycodiromaceis," in fasciculi (of imp. 8vo), each containing fifty numbers. Of Coleochæteæ, Œdogonieæ, Mesocarpeæ, Zygnemeæ, &c., only fertile examples will be included. The new species will have accompanying diagnoses in Latin. Each fasciculus will contain about sixty species. The price of each fasciculus is announced at 17s., carriage not included. Orders may be sent to Dr. Wittroch or Herr Nordstedt as above.

PROCEEDINGS OF SOCIETIES.

DUBLIN MICROSCOPICAL CLUB.

18*th January*, 1877.

Volutella ciliata, Fries, *and V. setosa*, Berk., *growing together, exhibited.*—Mr. Pim exhibited *Volutella ciliata*, Fries, and *V. setosa* Berk., growing together on a decaying Gladiolus bulb. The latter appears to be common on various decaying substances, such as orchid-bulbs; and whilst *V. ciliata* is rare, the specimens shown being the only ones Mr. Pim had seen, he remarked that he had found, some years ago, another form, possibly distinct, which had the mass of spores yellow, with hyaline bristles, whilst the mass of spores is white in *V. setosa*, and yellow with the bristles black in *V. melaloma*. It grew on decayed leaves of a species of Phocus.

Heliopelta perforata, O'M., *n. s.*, *exhibited.*—Rev. Eugene O'Meara exhibited a form of what might, on superficial inspection, be considered identical with *Heliopelta Metii*, Ehrenb., but, on a closer examination, it presented some remarkable points of disagreement. The triangular compartments, which constitute so conspicuous a feature of the form specified, are scarcely discernible in the present case. The central boss in the form exhibited is round, just as appears in *Coscinodiscus perforatus*; the areoles are roundish, radiate, smaller towards the centre and margin than in the intermediate portion of the valve. On the ground of these characters the form appears to be a distinct species, which he would name *Heliopelta perforata*, a name suggested by the resemblance of the central boss to that of *Coscinodiscus perforatus*.

Abies Williamsonii (Newberry), R. Brown, *in 'Herb.'* (*A. Hanburyana*, B. C.), *not the form cultivated under that name and sections of the leaves, exhibited.*—Professor McNab showed sections of the leaf of a pine from the herbarium of the Royal Botanic Garden, Edinburgh, with the label, "*Abies Williamsonii*, Newberry (*Abies Hanburyana*), B. C. Assoc., M.S. Puntledge Lake Mountains (in Vancouver's Island), V.I., Aug., 1864, Robert Brown." The specimen is unique, and the label is in the handwriting of Dr. Robert Brown.

An examination of the specimen showed that the forms cultivated in the Royal Botanic Garden, Edinburgh, under the names of *Abies Williamsonii* and *Abies Hamburyana*, have nothing to do with the species now under examination. The new form

resembles *Tsuga Hookeriana* at first sight, but is very different, and most closely approaching the plant cultivated in Glasnevin Botanic Garden, Dublin, as *Picea Alcockiana*, from Japan. It has a single fibro-vascular bundle in the leaf and two resin-canals, and, like Tsuga and Picea, the leaves are placed on a large cushion. The upper side of the leaf is white with stomata, and the two resin-canals, like those of *P. Alcockiana*, are situated close to the under surface, and about midway between the fibro-vascular bundle and the margin of the leaf.

The hypoderm is largely developed, more than in *P. Alcockiana*, and the leaf is more tetragonal than in the Japanese neighbour. An examination of the Vancouver's Island form shows that *Abies Williamsonii* is probably a distinct species, closely related to the Japanese one, and that all the specimens cultivated as *A. Williamsonii* are to be referred to the section Tsuga. The relation of a species from Vancouver's Island to the Japanese one is too interesting to be overlooked.

On a minute species of Cosmarium with smooth dark brown zygospores. (See 'Club Minutes' of Nov., 1876); the same also occurred in Italy.—Mr. Archer showed a preparation by Herr Nordstedt of Lund of a desmidian form, with zygospore, marked as *Sphærozosma excavatum*, cum zygosp., and collected by that observer in Italy. This was seemingly in every way, as regards the zygospore and otherwise, both in form and tint, quite identical with that Mr. Archer had exhibited at last November Club-meeting as a new species of Cosmarium, which he had proposed to name *Cosmarium minutissimum*. He had since then forwarded conjugated Irish examples to Mr. Roy, who completely agreed with him that the form belonged to Cosmarium, wanting, as it did, all trace of the minute connecting processes or papillæ appertaining to Sphærozosma; it was also (by comparison) considerably more minute than the joints of *Sph. excavatum*, besides being likewise of a different form. In *Sph. excavatum* the construction forms a rounded sinus on each side—in the form under consideration a minute acute incision; in the former the zygospore is colourless, in the latter very dark brown. There are some three or four of these excessively minute smooth forms of Cosmarium extremely like one another and but slightly differing in their dimensions (rather degree of minuteness!), but their differences, slight as they are and difficult to successfully pourtray on paper, *are there*, and seem constant, whilst not less so and more striking are their different zygospores. *Cosm. minutissimum* (here so-called), is quite a distinct thing from any of these.

Lejeunia patens, exhibited.—Dr. Moore showed a pretty and minute form of Lejeunia, *L. patens*, Lindl., which he had collected at Cromaglown (Killarney), and considered it an exactly similar form of that species to one collected by Dr. Spruce at a great elevation on the Peruvian Andes and named *L. patens*, var. *cochleata*. Like all the minute Hepaticæ, this formed a very pretty object viewed under a moderate power.

Structure of Gill on Centrostephanus Rodgersii.—Mr. Ma tosh exhibited one of the external gills of *Centrosteph Rodgersii* (A. Agassiz). It consists of an elongate axis or r along which are tufts of membrane, arranged in pairs, to n the distal end of the gill, where they become confluent i middle line and continue as a ridge to the termination. The of the gill is supported by a series of calcareous rods with ends overlapping each other, and scattered through the r the organ are numerous spicules varying from simple ro large perforated plates, very like but distinguishable from of *Strongylocentrotus lividus* figured by Valentine in his ' tomie du genre Echinus,' (in Agassiz's 'Monographies des I nodermes'). An external gill of *Echinus esculentus*, Linn., also shown for the sake of contrast.

New species of Chytridium, parasitic on Ectocarpus pusill— Dr. E. Perceval Wright exhibited specimens of a new speci Chytridium parasitic in the cells of *Ectocarpus pusillus.* some of the twigs of the Ectocarpus almost every second contained a specimen of the parasite, which often caused growth of the plant to become pushed into an irregular knobbed form. When first observed the circular Chytridian were regarded as oval "fruits" of the Ectocarpus, but on development being watched side by side with that of the tri sporangia with which the Ectocarpus was crowded, the differ in the spores was shortly quite apparent—those of the Ch dium being uniciliated, and the nucleus of each spore the indication of spore-formation; whilst those of the trichosp gium were as described by Thuret and quite of an algal chara Specimens of *Ectocarpus crinitus*, Harvey, were shown in as described by Harvey, which fruit was, without doubt, the s species of Chytridium as now described. Specimens of *Ectoca Mertensii* were also shown to prove that the so-called "utric fruits" were really only modified trichosporangia, and it suggested that possibly the oosporangia of Thuret might, in s cases, be either modified trichosporangia or parasitic Chytrid

15*th February*, 1877.

Microscopic Structure of Noble Opal.—Professor E. I F.R.S., exhibited under the microscope a thin section of n opal from Australia. The specimens of opal in this instance contained in a sort of tufaceous material, of a brownish col highly vesicular, not calcareous, and of unknown origin. opals were exceedingly numerous in the paste, of various size to a quarter of an inch, and of varying characters, from semi- to rich fiery or noble opal. The smaller specimens were the opalescent.

The slice under a high power exhibited some minute cel intervals, but these were apparently unconnected with the perty of opalescence. In the portion of the specimen more

tensely opalescent, of a darker colour, and distinctly banded (bands of deposition), numerous short, irregular fissures or scars, generally curved and intersecting, were observed. No light, however, was thrown upon the origin of the opalescent property of the mineral until the slice was examined with the aid of the polariscope, the Nicol's prisms being crossed, and with a very strong light. Under these conditions the structure of the mineral became splendidly evident. The whole surface was seen to be diversified by short, wedge-shaped bands of green, crimson, pink, yellow, and gold colours, rudely parallel, pointing inwards from the edge of the specimen, and transverse to the "bands of deposition" above described. In favorable positions distinct fissures, *inferred to be due to the intersection of oblique planes with the plane of the thin slice,* were observed to coincide with the changes of colour, and it became evident that the opalescence was intimately connected with, if not directly due to, the existence of such planes.

Mr. Hull considered these planes to be due to shrinkage, originated upon the formation of mineral by aqueous deposition in the cells of the tufa. In some cases the fissures appeared to be wedge-shaped, or to converge from opposite directions upon other predominant lines of fissure, so that the corresponding planes of shrinkage would form minute, irregular prisms, giving rise to the play of colours as the light was reflected from the planes and refracted through the mineral in various directions.

These observations appeared to bear out, to some extent, the views of Sir David Brewster, who attributed the calorific effects of opal to "minute pores or vacuities arranged in parallel lines forming planes, various such planes being placed close to each other, so as to occupy a space with three dimensions." He also adds, "these pores exhibit a crystalline arrangement like the lines of sapphire" ('Edin. New. Phil. Journ.,' xxxviii, 1845).

Seed of Castilleja indivisa, exhibited.—Mr. Pim showed the seeds of *Castilleja indivisa.* The seed was invested with a large and beautifully reticulated testa similar to that of Pyrola, forming a netted sac many times longer than the contained embryo.

Structure of Spines of Cidaris tribuloides, Lamk., *C. metularia,* Blainv. and *C. Thouarsii,* Val.—Mr. Mackintosh exhibited transverse sections of the spines of the above three species, the only ones retained in the genus by A. Agassiz in his recent 'Revision of the Echini.' The first of these can readily be discriminated by the open nature of the external crust, in this resembling the spines of *Goniocidaris geranoides,* Lamk. (Club. Minutes, August, 1876). The other two have a more solid crust, but in *C. metularia* the axial reticulation has thick bars, whilst in *C. Thouarsii* they are very slight.

Abnormal leaves of a species (or var.) of Abies from Japan, a possible hybrid between A. bifida and A. firma.—Dr. McNab exhibited sections of the leaves of a pine from Japan. The speci-

mens were from the collection of Messrs. Veitch and Sons, Chelsea, and were obtained by the late Mr. J. Goold Veitch, in Japan, and were given to Dr. McNab by Messrs. Veith as *Abies firma*. An examination of the leaves showed that they possessed characters intermediate between *Abies firma* and *Abies bifida* as described by Dr. McNab in his paper in the 'Proceedings of the Royal Irish Academy.' The leaves have much thickened hypoderma but possess the thickened idioblasts so characteristic of *A. bifida*, but instead of having two resin canals close to the lower epidermis, four resin canals were developed, two in the position in the parenchyma in which they are met with in *A. firma*, and two nearly in the position they occupy in *A. bifida*, but instead of being in contact with the lower epidermis they are separated from it by a few chlorophyll-bearing cells.

Plants raised from the seeds obtained from cones similar to those examined do not possess the four resin canals, but have two in the position in which they are found normally in *A. bifida*, although a slight irregularity in position has been recorded by Dr. McNab.

The leaves of the Japanese specimens of Messrs. Veitch are therefore remarkably abnormal, and a possible solution of the difficulty seems to be that the cones brought by Mr. Goold Veitch were those of a hybrid between *A. bifida* and *firma*, the characters of these two forms being blended; that the ovules had been fertilized by the pollen of *A. bifida*, hence the seedlings raised from the Japanese cones have returned almost completely to *A. bifida*. If this suggestion be found tenable it will clear up a difficulty of long standing about these two Japanese species.

Cosmarium-form coming close to Cosm. Hammeri, Reinsch, *and C. homalodermum*, Nordstedt, *exhibited, its identification as yet in abeyance.*—Mr. Crowe showed one of those rare and interesting Cosmarium-forms very difficult to determine, and yet such as one can see at a glance is not identical with that typical and probably pretty common form with which it shows the nearest relationship. The form now shown was likely to be either *Cosmarium Hammeri*, Reinsch, or *C. homalodermum*, Nordstedt, or it might possibly not be identical with either, a point difficult to determine, but it was very evidently distinct from any suppositional form of, for instance, the common species *C. pyramidatum*. Mr. Archer also had taken the present form in one or two places, but it is undoubtedly very rare in Ireland; the present examples were taken near Woodenbridge, Co. Wicklow. This form is about one third longer than broad, lateral margins of semi-cells concave, upper margins convexo-truncate, in side view rounded, a minute tooth-like protuberance visible just at the suture, in end view elliptic.

Brightwellia Johnsoni, exhibited.—Rev. E. O'Meara exhibited a specimen of *Brightwellia Johnsoni* from Cambridge Estate deposit, Barbadoes.—By a coincidence Mr. Robinson, too, had brought for exhibition a specimen of the same fine species.

List of Diatomaceous species found in a Sample of Earth from Germany, said to be employed in the manufacture of Dynamite.—Dr. Barker showed, on the part of Mr. A. M. Vereker, a sample of Diatomaceous earth from some locality in Germany; the material is said to be employed in the manufacture of dynamite. Mr. O'Meara identified the species and furnished the following list:

Amphora ovalis, *A. minutissima*, *Cocconema lanceolatum*, *C. parvum*, *Cymbella cuspidata*, *C. maculata*, *Cyclotella operculata*, *Epithemia alpestris*, *E. argus*, *E. Hyndemanii*, *E. longicornis*, *E. sorex*, *E. turgida*, *E. zebra*, *Gomphonema intricatum*, *G. dichotomum*, *Navicula Anglica*, *N. lacustris*, *N. limosa*, *N. limosa*, var. *gibberula*, *N. affinis*, *N. dubia*, *Orthosira arenaria*, *Synedra amphirhyncus*, *S. longissima*, *S. ulna*.

Microsporon mentagrophytes, exhibited.—Dr. W. M. A. Wright showed filaments of the hair-parasite *Microsporon mentagrophytes*, disputed by some as being only an abnormal or disorganized condition of the hair.

On the antheridia in Polysiphonia nigrescens.—Professor E. Perceval Wright exhibited the quite recently gathered antheridia of *Polysiphonia nigrescens*. So far as he knew, the descriptions of the antheridia in this genus left much to be desired, and the figures of them in most works on descriptive algology gave only the appearances as seen in dried specimens. In the specimens of the above species gathered early in February, the antheridia appeared to arise in an outgrowth of what, in contrast to the "siphonal cells," might be called the "cortical cells," of the extreme sides of the twigs, the antheridial cell being the enlarged basal cell of a trichome-like prolongation which started from one of the cortical cells, which itself projected at an angle from the main twig; above the enlarged basal cell there were to be found, when the structure was complete, from five to seven other cells gradually tapering to a hair-like point; these were most easily broken off. Surrounding the antheridial cell and its hair-like prolongation were a series of long dichotomously divided filaments, which, when the entire mass was observed in a growing state, seemed to act as conducting or collecting hairs for the antherozoids, which made their escape through the ruptured cell-wall of the antheridium. The antherozoids themselves, when freshly escaped, seem to be provided with no very definite cell-wall, neither did they seem to be the products of special mother-cells, but rather specialised portions of the protoplasmic contents of the antheridial cell.

On a Cosmarium-form seemingly the same as Jacobsen's so-called var. of Cosm. Brébissonii.—Mr. Archer showed examples of a small form of Cosmarium from Co. Carlow. This comes near to the form figured by Jacobsen in 'Copenhagen Journal of Botany,' t. vii, f. 15, under the name of "*Cosmarium Brébissonii*, forma genuina, latior et angustior." It is utterly out of the question to identify the very common and easily recognised and very large

form as defined by Ralfs as *Cosm. Brébissonii*, with Jacobsen's far smaller and very different form. One can only marvel how he could think for one moment of regarding these two widely distinct forms as falling under one and the same species; upon such principles it would be useless and almost hopeless to arrive at any clear idea of the forms that really exist and "what's what." If Ralfs could be proven wrong in annexing the name *Cosmarium Brébissonii* to the handsome form now so well known by that designation, why be it so, and give *it* a *new* name; but Jacobsen's wants a name of its own, and one would fancy it would only lead to confusion to call the latter *Cosm. Brébissonii*. But why not let well alone? Whether the form now exhibited be one and the same with Jacobsen's, would probably be very difficult of determination in the absence of an authentic specimen from Jacobsen himself; it did not seem *thoroughly* to agree with it, yet there seems no published figure coming closer to it. Be that as it may, *it* might just as well be made a "variety" of *Cosm. tetrepthalimum, biretum, margaritiferum*, &c., as of *Cosm. Brébissonii* (as commonly understood), which stands very well indeed on its own basis. The form exhibited was under medium size or small; constriction deep, linear; lower angles very acute, rectangular; lateral margins for a time vertical, then arching round to form very broadly rounded upper angles, which merge into the subtruncate upper margin; lateral margins irregularly serratulo-undulate, the crenatures so formed becoming somewhat smaller upwards, presently becoming obsolete; on upper angle and upper margin nearly smooth; front surface granulate, granules faint and scattered; end view fusiform-elliptic.

MEMOIRS.

The DOCTRINE *of* CONTAGIUM VIVUM *and its* APPLICATION *to* MEDICINE. By WILLIAM ROBERTS, M.D., F.R.S., Physician to the Manchester Royal Infirmary; Professor of Clinical Medicine in Owens College.

[Address in Medicine, delivered at the meeting of the British Medical Association at Manchester, August, 1877.]

GENTLEMEN,—The notion that contagious diseases are produced by minute organisms has prevailed in a vague way from a remote age; but it is only within the last twenty years—since the publication of Pasteur's researches on fermentation and putrefaction—that it has assumed the position of a serious pathological doctrine. In the last decade, startling discoveries of organisms in the blood have given this doctrine the support of actual observation; and its application as a guide in the treatment of wounds by Professor Lister has made it a subject of universal interest to medical practitioners.

The resemblance between a contagious fever and the action of yeast in fermentation—or the action of bacteria in decomposition—is in many points so striking that it is difficult to avoid the impression that there is some real analogy between them. If, for example, we compare the action of yeast with smallpox, this resemblance comes out very distinctly, as the following experiment will show. I filled two pint bottles, A and B, with fresh saccharine urine, and inserted a delicate thermometer in each. A was inoculated with a minute quantity of yeast, but nothing was added to B. Both bottles were then placed in a warm place in my room, at a temperature of about 70 deg. Fahr. In order to get a correct standard of temperature for comparison, I placed beside these a third bottle, C, filled with water, and inserted a delicate thermometer in it. All these bottles were carefully swathed in cotton-wadding, for the

purpose of isolating their individual temperature, and to obviate, as much as possible, the disturbing effects of the varying temperature of the room. For twelve hours no change took place; but, at the end of that time, A began to ferment, and the thermometer marked a distinct elevation of temperature. On the second day, A was in full fermentation, and its temperature was 2·7 deg. above B and C. This disturbance continued for five days, the temperature ranging from two to three degrees above the companion bottles. The disturbance than subsided, and the temperature fell to an equality with B and C, and a considerable sediment, composed of yeast, settled at the bottom. In the meantime, B showed little alteration; but, on the sixth day, it began to ferment, the temperature went up, and for more than a week its thermometer stood about two degrees above A and C. Finally, the temperature in B declined, the disturbance subsided, and the newly formed yeast settled to the bottom of the vessel.

This fever in a bottle resembled smallpox in the following points. A period of incubation intervened between inoculation and then commencement of disturbance; then followed a period of disturbance accompanied by elevation of temperature; this was succeeded by a subsidence of the disturbance and a return to the normal state. Great multiplication of the infective material (or yeast) took place during the process, and, after its conclusion, the liquid was protected from further infection with the same contagium. We likewise notice that the contagium of fermentation, like that of smallpox, may take effect either by direct purposive inoculation or by fortuitous infection through the atmosphere. In both cases, the infective material has the power of preserving its activity for an indefinite period. The comparison fails in at least one important point—in the fermented urine, sugar is replaced by alcohol and carbonic acid; but we are not aware that any pronounced chemical changes occur in the blood or tissues during an attack of smallpox. I would, moreover, carefully guard myself against being supposed to suggest that the enhanced temperature in the fermenting urine is a real analogue of the preternatural heat of fever.

Let me direct your attention to another example—a kind of partial decomposition or fermentation which takes place in boiled hay-infusion when it is inoculated with the *Bacillus subtilis*. The *Bacillus subtilis* is a very common bacterium found in vegetable infusions and in curdling milk. I hope you will take note of this little organism; for I shall have

to refer to it more than once in the course of this address. I took a flask containing hay-infusion, which had been sterilised by boiling, and inoculated it with a drop of fluid swarming with *Bacillus subtilis*. After the lapse of twenty-four hours, the previously transparent infusion became turbid. This turbidity increased, and, on the second day, a film or crust formed on the surface of the infusion. On the third and subsequent days, the crust broke up and fell in pieces to the bottom of the vessel. In about a fortnight, the turbidity passed away, and the original transparency of the infusion was perfectly restored, so that it looked exactly as it did before the process began, except that there was now a sediment consisting of the spores of the little organism at the bottom of the flask. In this case, again, there was the same succession of events: a period of incubation, followed by a period of disturbance, succeeded by a period of subsidence, and, finally, restoration to the normal state. There was also great increase of the infective material and immunity from further attack by the same contagium.

The yeast-plant and the *Bacillus subtilis* may be taken as representatives of a large class of organisms in regard to which we are only beginning to realise their vast importance in the economy of Nature and in the life of man. They are, as I shall presently show, the essential agents in all fermentations, decompositions, and putrefactions. We may group them together for the convenience of description under the general designation of *saprophytes*, a term intended to include under one heading all the organisms associated with the decomposition and decay of organic matter. The yeast plant and its allies, and all the numerous species and varieties of bacteria, belong to this group. In size and form, they are among the smallest and simplest of living things, but their vital endowments are wonderful.

All the organisms hitherto found associated with infective inflammations and contagious fevers belong to the tribe of bacteria, and we cannot advantageously enter on a study of that association without a knowledge of the origin and attributes of these organisms. This brings us into a field of active controversy. It has been alleged, as you know, on high authority, that these organisms, under certain conditions, depart entirely from the universal law of generation, which is expressed in the aphorism *omne vivum è vivo*, and that they may arise spontaneously by a process of abiogenesis. It is also alleged that these organisms are not the actual agents of decomposition, but are merely associated with that process as *secondary or accidental* accompaniments. I pro-

pose to lay before you evidence that both these allegations are unsustainable, and to prove that bacteria, like other organisms, arise from pre-existing parent germs, and in no other way, and that they are the actual agents in all decomposition and putrefaction.

The first proposition I shall endeavour to establish is this; that organic matter has no inherent power of generating bacteria, and no inherent power of passing into decomposition.

I have here placed before you samples of three sets of preparations, out of a large number in my possession, which serve to substantiate this proposition.

The first set consists of organic liquids and mixtures which have been rendered sterile by a sufficiently prolonged application of the heat of boiling water. They are composed of infusions of vegetable and mineral substances, fragments of meat, fish, albumen, and vegetables, floating in water. They are contained in oblong glass bulbs, and are protected from the dust of the air by a plug of cotton-wool inserted into the necks of the bulbs, but freely pass to its gaseous elements, which pass in and out through the cotton-wool. They are all, as you see, perfectly transparent and unchanged, though most of them have been in my possession for several years.

The second set consists of organic liquids which have been simply filtered under pressure through unglazed earthenware into sterilised flasks. They include acid and neutralised urine, albuminous urine, diluted blood, infusions of meat and of hay. As these preparations were obtained by a method which is in some respects new, I will describe it to you. A piece of common tobacco-pipe, about six inches long, served as the filter. This was secured by india-rubber piping to the exit-tube of one of the little flasks used by chemists for fractional distillation. The flask is first charged with distilled water, and then a tight plug of cotton-wool is inserted into its neck. The flask is next set a-boiling briskly over a lamp. The steam rushes through the cotton-wool plug and through the tobacco-pipe, clearing both these passages of any germs they might contain. When the water has nearly boiled away, the end of the tobacco-pipe is hermetically sealed with melted sealing-wax. After a little more boiling, the flame is withdrawn and the neck of the flask is instantly closed with a tight vulcanite cork. The apparatus is now ready for action, and the tobacco-pipe is immersed in the liquid to be filtered. When the flask cools, a vacuum is created within it, and this serves as a soliciting force to draw the liquid through the earthenware into the flask. The pro-

cess of filtration is very slow; it takes two or three days to charge the flask. When a sufficiency has come over the apparatus is removed and placed on a shelf for a few days until the pressure inside and outside the flash is equalised. The vulcanite cork is then withdrawn, and the exit-tube is separated and sealed in the flame of a lamp. In this way, you obtain a sterilised flask charged with the filtered organic liquid, and protected from outside contamination by a plug of cotton-wool. Preparations obtained in this way, if due precaution have been used in the manipulation, remain permanently unchanged; organisms do not appear in them, and decomposition does not ensue.

The third set of preparations are in some respects the most significant of the three. They consist of organic liquids which have been simply removed from the interior of the living body, and transferred, without extraneous contamination, into purified glass vessels. I will not detain you with the methods employed to obtain them; it is sufficient to say that, by the use of proper precautions, it is possible to convey blood, pus, urine, ascitic fluid, pleuritic effusion, blister serum, or the contents of an egg into sterilised glass vessels without contact with any infecting agency. Preparations thus obtained are exhibited in these flasks; they are protected from air-dust by a simple covering of cotton-wool. All of them are absolutely free from organisms and from any signs of decomposition.

What meaning can we attach to these preparations? You all know that liquids and mixtures such as these speedily decompose and swarm with organisms when left to themselves exposed to the air. They are of most varied composition, and the most apt of all known substances to breed bacteria and to become decomposed. They have been exposed to the most favorable conditions in regard to warmth, moisture, and air. Many of them have been in my possession several years, and all of them for several months, yet they are wholly barren and without sign of decomposition. I venture to say that these preparations substantiate in a positive manner the proposition with which we started; namely, *that organic matter has no inherent power of generating bacteria and no inherent power of passing into decomposition.*

A second proposition is likewise established by these preparations; namely, *that bacteria are the actual agents of decomposition.*

In all these preparations, the absence of bacteria coincides with the absence of decomposition. If I were to cause bacteria to appear in them, either by purposive infection or by

exposing them to the unfiltered air, decomposition would infallibly follow. The filtration experiments supply a new and telling argument on this point. Some of the liquids become decomposed and full of bacteria while the filtration was going on, but the part which came over into the flasks remained without further change, showing that decomposition cannot go on without the actual contact of the living organisms.

We have next to ask ourselves what are the sources and what is the nature of the fecundating influence which causes organic liquids, when abandoned to themselves without protection, to become peopled with organisms. In regard to their source, the answer is not doubtful. If I remove the covering of cotton-wool from any of these preparations, and admit unfiltered air, or a few drops of any ordinary water, however pure, or anything that has been in contact with air or water, organisms make their appearance infallibly in a few hours. As to the nature of the infective agents, we can say positively that they must consist of solid particles, otherwise they could not be separated by filtration through cotton-wool and porous earthenware. Is it not a most natural inference that they are the parent germs of the brood which springs up at their impact? They are, however, so minute that we cannot identify them as such under the microscope; but Professor Tyndall has demonstrated that air which is optically pure—that is, air which is free from particles—has no fecundating power.

It is contended in some quarters that these particles are not living germs of any sort, but simply particles of albuminoid matter in a state of change which, when they fall into an organic liquid, communicate to it their own molecular movement, like particles of a soluble ferment, and so produce decomposition, which, in its turn, provides the conditions necessary for the abiogenic generation of bacteria. Filtration through porous earthenware furnishes a complete answer to this theory; for I found on trial that the soluble ferments passed with ease through the porous earthenware. If, therefore, this theory were true, the filtered liquids, if already commencing to be decomposed, would go on decomposing, and would develope bacteria after filtration; but instead of that they remain unchanged and barren. We are absolutely driven to the conclusion that these particles are living germs; no other hypothesis squares in the least degree with the facts of the case.

We may formulate this conclusion in a third proposition as follows: *The organisms which appear as if spontaneously*

in decomposing fluids owe their origin exclusively to parent germs derived from the surrounding media.

But how, you will ask, has it been possible, in the face of this evidence, to maintain, with a show of success, the contrary opinion that bacteria can and do, exceptionally at least, and in certain media, arise spontaneously? This opinion is based on two undoubted facts, which, taken together, seem at first sight to stand in direct contradiction with the propositions I have enunciated. The first fact is that bacteria are invariably killed when exposed to a temperature of about 140 deg. F., or any higher temperature. The other fact is that certain liquids, such as neutralised hay-infusion and milk, often produce bacteria after having been boiled, sometimes after being boiled for two or three hours, and when there was no possibility of subsequent infection. It seemed at first sight a fair inference from these two facts that the apparition of organisms in boiled liquids was due to spontaneous generation, or abiogenesis. It does seem difficult to believe that any living thing can survive a boiling heat for several hours, and yet such is undoubtedly the truth. When I published on this question in 1874, I advanced more than one line of proof which appeared conclusive that germinal particles of some sort did, under certain circumstances, survive a boiling heat; and that the instances referred to were examples of such survival, and not of a *de novo* generation. But I was not then able to explain the apparent contradiction involved in these experiments.

Since then, a new and surprising light has been thrown on this subject by the researches of Professor Cohn of Breslau, and we are now in a position to offer a complete solution of the riddle. All the confusion has arisen from our having failed to distinguish between the growing organism and its seed or spore. You are all familiar with the immense difference in vital endurance between the seed and the growing plant. The same difference exists between a spore and its offspring. Some spores have an extraordinary power of resisting heat. Mr. Dallinger and Dr. Drysdale, in the course of their inquiries into the life-history of septic monads, demonstrated that while the living monads are killed by a heat of 140 deg. F., the spores of one variety, which are so minute that they cannot be seen, except in mass, by the highest powers of the microscope, are capable of germinating after being subjected to a heat of 300 deg. F. for ten minutes! If the spores of monads can resist this tremendous heat, there is no reason why the spores of bacteria should not be able to survive the feebler heat of boiling water.

The development of bacteria in hay-infusion, after having been boiled continuously for several hours in hermetically sealed vessels, seemed to furnish the very strongest attainable evidence in favour of the abiogenic origin of these organisms; and yet, by a singular fatality, the investigations of Cohn have shown that this evidence, rightly interpreted, supplies a crowning argument against that view.

Cohn had the curiosity to examine the organisms which arose under these extraordinary circumstances. Did he find a new birth? On the contrary, he recognised a familiar form; none other than our old acquaintance the *Bacillus subtilis.* He followed it through all the stages of its development. It first appeared some twenty-four hours after the boiling, in the form of innumerable short moving rods. On the second day, these rods shot out into long threads; on the third day, there appeared on the threads, at perfectly regular intervals, strongly refractive oval bodies, which he identified as spores. Finally, the threads broke down and the spores were set free. In many hundred observations, he saw this one organism and no other, and witnessed the successive stages of its development occurring with the constancy of a physical experiment.

Now, let me ask if this looks like an act of abiogenesis. The evolutionist demands, for the transformation of one organic type into its next descendant, myriads of generations, and I know not what lapse of ages. But here, if this be a case of abiogenesis, we see accomplished at one leap, in a single generation, and in seventy hours, not merely the bridging over of the gulf between the dead and the living, but the development of a specifically distinct organism, with definite form, dimensions, and mode of growth, and furnished with a complete provision for the reproduction of the species! I need scarcely say that such a feat would be, not only without parallel in the history of evolution, but would be wholly contradictory to that theory.

The only group of bacteria, so far as is known, which form spores are the *Bacilli;* and Cohn remarks that in all the various cases in which he had observed organisms to arise in boiled liquids, they belonged in every instance to the *Bacilli.*

Before leaving this part of my subject, I wish to suggest certain considerations in regard to the nutrition and function of saprophytes, which appear to me to render it in the highest degree improbable that spontaneous generation should ever be discovered in this quarter. If it be assumed that the occurrence of abiogenesis, at some time in the past history of the globe, is a necessary postulate in science, and

I see nothing unscientific, looking to the law of continuity in the operations of nature, in the supposition, that it is occurring at the present day somewhere or other on the earth's surface, but certainly not in decomposing liquids.

Saprophytes are, as is well known, destitute of chlorophyll, and, like all such plants, they are unable to assimilate carbonic acid. They obtain their carbon exclusively from more complex compounds which have been prepared for them by pre-existing living beings. It is, therefore, manifestly impossible that the primordial forms of life could have belonged to this group; for if we throw ourselves back in imagination to that remote era when life first appeared on the globe, we should find ourselves in a purely inorganic world, amid conditions in which saprophytes could not possibly live nor obtain nourishment. The special function of saprophytes in the order of nature is to destroy, not to create, organic matter; and they constitute the last, not the first, link in the biological chain. For if we regard the order of life as it now proceeds on the earth's surface, we may describe it as beginning with the chlorophyll body, and ending with the saprophyte. The chlorophyll body is the only known form of protoplasm which obtains all its nutriment from inorganic sources; here integration is at its maximum, and disintegration at its minimum, and the resultant of the nutritive operations is increase of organic matter. The saprophyte, on the contrary, feeds on nutriment prepared for it by other beings; here integration is at its minimum, and disintegration at its maximum, and the resultant of the nutritive process is decrease of organic matter. What takes place in a decomposing liquid, under the action of saprophytes, is progressive disintegration, and finally a breaking up of all the organic compounds it contains into carbonic acid and ammonia; and the process ends with the mutual destruction of the organisms themselves. Organisms could not, therefore, begin in this way. The primordial protoplasm must have been either the chlorophyll body itself, or a body having a similar mode of nutrition.

If the search for contemporary abiogenesis is to be continued, as doubtless it must be, for science is insatiable, it appears to me that the inquirer should endeavour to realise the conditions under which abiogenesis must have occurred in the first instance. For, if the process be going on amongst us at this day, it may be assumed as probable that it still proceeds on the original lines laid down at the dawn of life. If ever I should be privileged to witness an abiogenic birth, I should certainly not expect to see a saprophyte; I should

rather expect to see a speck of protoplasm slowly formed, without definite shape or dimensions, and nourishing itself, like the chlorophyll body, on a purely mineral diet. The more one reflects on this subject, the more clearly does it appear that the spontaneous origin of saprophytes is logically impossible. Speaking as an evolutionist, I should rather infer that saprophytes were a late development; probably a degradation from some algal forms which had found their profit in feeding on waste organic matter, and which gradually lost their chlorophyll through want of use, and with it their power of feeding on an exclusively mineral diet.

We now approach the more practical side of our subject; that which concerns us as practitioners of medicine and students of pathology. I have already directed your attention to the analogy between the action of an organised ferment and a contagious fever. The analogy is probably real, in so far at least that it leads us to the inference that contagium, like a ferment, is something that is alive. We know of nothing in all our experience that exhibits the phenomena of growth and self-propagation except a thing possessed of life.

This living something can only be one of two things; either it is an independent organism (a parasite) multiplying within the body or on its surface, or it is a morbid cell or mass of protoplasm detached from the diseased body and engrafted on the healthy body. Possibly, both these conceptions may have their application in the explanation of different types of infective disease. In regard to the latter conception, however, the graft theory, which has been so ably developed by my friend Dr. Ross, I will only say that it has not, as yet, emerged from the region of pure speculation. It lacks an established instance or prototype; and it fails to account for the long-enduring dormant vitality so characteristic of many contagia, which conforms so exactly with the persistent latent vitality of seeds or spores, but which contrasts strongly with the fugitive vitality of detached protoplasm.

If, then, the doctrine of a contagium vivum be true, we are almost forced to the conclusion that a contagium consists (at least in the immense majority of cases) of an independent organism or parasite, and it is in this sense alone that I shall consider the doctrine.

It is no part of my purpose, even if I had the time, to give an account of the present state of knowledge on this question in regard to every contagious disease. My object is to establish the doctrine as a true doctrine; to produce

evidence that it is undoubtedly true in regard to some infective inflammations and some contagious fevers. In an argument of this kind, it is of capital importance to get hold of an authentic instance; because it is more than probable, looking to the general analogy between them—that all infective diseases conform in some fashion to one fundamental type. If septic bacteria are the cause of septicæmia—if the spirilla are the cause of relapsing fever—if the *Bacillus anthracis* is the cause of splenic fever—the inference is almost irresistible that other analogous organisms are the cause of other infective inflammations and of other specific fevers.

I shall confine my observations to the three diseases just named: septicæmia, relapsing fever, and splenic fever; merely remarking that, in regard to vaccinia, smallpox, sheep-pox, diphtheria, erysipelas, and glanders, the virus of these has been proved to consist of minute particles having the character of micrococci; and that, in regard to typhus, scarlet fever, measles, and the rest of the contagious fevers, their connection with pathogenic organisms is as yet a matter of pure inference. For further details, I must refer you to the able reports of Mr. Braidwood and Mr. Vacher on the 'Life-history of Contagium,' made on behalf of this Association, and published in the Journal in the course of the past and present years.

SEPTICÆMIA.—We will first inquire how it stands with this doctrine in regard to traumatic septicæmia and pyæmia. You are all aware that foul, ill-conditioned wounds are attended with severe, often fatal, symptoms, consisting essentially of fever of a remittent type, tending to run on to the formation of embolic inflammations and secondary abscesses.

The notion that septicæmia is produced by bacteria, and the *rationale* of the antiseptic treatment which is based thereupon, is founded on the following series of considerations:

1. It is known that decomposing animal substances—blood, muscle, and pus—develope, at an early stage of the process, a virulent poison, which, when injected into the body of an animal, produces symptoms similar to those of clinical septicæmia. This poison is evidently not itself an organism; it is soluble, or at least diffusible, in water, and it is capable, by appropriate means, of being separated from the decomposing liquid and its contained organisms. When thus isolated, it behaves like any other chemical poison; its effects are proportionate to the dose, and it has not the least power of self-multiplication in the body. To this substance,

Dr. Burdon Sanderson has given the appropriate name of pyrogen. It is the only known substance which produces a simple uncomplicated paroxysm of fever—beginning with a rigor, followed by a rise of temperature, and ending (if the dose be not too large) in defervescence and recovery.

2. We know further, from the evidence I have laid before you, that decomposition cannot take place without bacteria, and that bacteria are never produced spontaneously, but originate invariably from germs derived from the surrounding media. We are warranted by analogy in regarding pyrogen as the product of a special fermentation taking place in decomposing albuminoid mixtures, but we cannot name the particular organism nor the particular albuminoid compound which are mutually engaged in the process.

3. In the third place, we know that when a wound becomes unhealthy, as surgeons term it, the discharge become offensive—in other words, decomposed—and when examined under the miscroscope they are found to swarm with organisms resembling those found in all decomposing fluids. Meanwhile the patient becomes feverish, and suffers from the train of symptoms which we call septicaæmia.

It is a natural inference that what takes place in decomposing blood or muscle in the laboratory takes place also in the serous discharges and dead tissues of the wound. These become infected from the surrounding air, or from the water used in the dressings, with septic organisms; on that follows decomposition and the production of the septic poison, or pyrogen; the poison is absorbed into the blood, and septicæmia ensues.

It was the distinguished merit of Lister to perceive that these considerations pointed to a means of preventing septicæmia. He argued that if you could prevent the access of septic organisms to the wound, or destroy them there, you would prevent decomposition, prevent the production of the septic poison, and thus obviate the danger of septicæmia. It is not within the scope of this address to describe the means by which Lister attained this object, still less to pass judgment on his practice, but I may be permitted to express my belief that the principle on which the treatment is founded is unassailable.

We should probably differ less about the antiseptic treatment if we took a broader view of its principle. We are apt to confound the principle of the treatment with Lister's method of carrying it out. The essence of the principle, it appears to me, is not exactly to protect the wound from the septic organisms, but *to defend the patient against the septic*

poison. Defined in this way, I believe that every successful method of treating wounds will be found to conform to the antiseptic principle, and that herein lies the secret of the favorable results of modes of treatment which at first sight appear to be in contradiction to the antiseptic principle. Take, for example, the open method of treating wounds, which is sometimes compared in its results with Lister's method. What is this treatment but another way (only less ideally perfect than Lister's) of defending the patient against the septic poison? Because, if the surgeon succeeds in providing such free exit for the discharges that there is no lodgment of them in the wound, either they pass out of it before there is time for the production of the septic poison, or if any be produced, it escapes so quickly that there is not enough absorbed to provoke an appreciable toxic effect.

Before we can understand the pathology of septicæmia we must have clear ideas on the relation of septic bacteria to our bodies. We see in our laboratories that dead animal tissues, when exposed to ordinary air or ordinary water, invariably breed septic organisms; in other words, contact of the septic germs with the dead tissues never fails to produce successful septic inoculation. But it is quite otherwise with the same tissues when alive and forming part of our bodies. You cannot successfully inoculate the healthy tissues with septic bacteria. It has been proved over and over again that these organisms, when separated from the decomposing medium in which they grow, can be injected in quantity into the blood or tissues of a healthy animal, or applied to a sore on its skin, without producing the least effect. The healthy living tissues are an unsuitable soil for them; the cannot grow in it; or, to put it in another way, ordinary septic bacteria are not parasitic on the living tissues.

The fact is of fundamental importance in the discussion of the pathology of septicæmia. We have a familiar illustration of its truth in the now common practice of subcutaneous injection. Every time you make a subcutaneous injection you inject septic germs into the tissues. I had the curiosity to test this point with the morphia solution used for this purpose in the Manchester Infirmary. I injected five drops of this solution into four flasks of sterilised beef-tea which had remained unchanged in my room for several months, taking care to avoid any other source of contamination. In forty-eight hours they were all in full putrefaction. But we know that no such effect follows when similar injections are made into the bodies of our patients.

It seems also probable that septic organisms enter con-

stantly into our bodies with the air we breathe and the food we take; they pass, presumably, like any other minute particles, through the open mouths of the lymphatics and lacteals, and penetrate some distance into these channels; they certainly come in contact with the accidental cuts, sores, and scratches which so often bedeck our skins. Notwithstanding all this, our bodies do not decompose; indeed, if ordinary septic organisms could breed in the living tissues as they do in the same tissues when dead, animal life would be impossible, every living creature would infallibly perish. How these organisms are disposed of when they do enter our bodies accidentally, as it were, in the various ways I have suggested, we cannot say; we can only suppose that they must speedily perish, for we find no trace of them in the healthy blood and healthy tissues.[1]

Bearing in mind, then, that ordinary septic organisms cannot breed in the living tissues, unless, at least, they are reduced to near the moribund state; bearing also in mind that there is a sharp distinction to be drawn between the septic poison and the organisms which generate it, we are in a better position to consider the course of events in a wound, which leads on to septicæmia and pyæmia. What probably takes place is this: An unprotected wound receives infection from the septic organisms of the surrounding media. If the discharges are retained in the sinuosities of the wound, decomposition of them sets in with production of the septic poison. This is absorbed into the blood, a toxic effect follows, and septicæmia is established. As this effect increases with the continuous absorption of the poison, the vitality of the system is progressively lowered, and especially the vitality of the tissues bordering the wound, which may be topically affected by the poison which percolates through them. These tissues at length become moribund or die outright; the septic organisms then invade and breed in them, more septic poison is produced and absorbed; the toxæmia becomes intense, embolic centres of inflammation and suppuration are formed, and the end comes. In all this history there is no necessity to assume, nor even a probability, that septic organisms invade, or at least multiply, in the blood.

[1] Exception must apparently be made in regard to the tissues and organs in the immediate vicinity of the absorbent surfaces. Both Klebs and Burdon Sanderson found that portions of the liver and kidneys removed from the body without extraneous contamination, produced bacteria, contrasting in this respect with the blood and muscles.—'British Medical Journal,' Feb. 13th, 1875.

They may do so at the near approach of death, but scarcely before that period.

In the course of traumatic septicæmia there sometimes occurs an event of great importance which imparts a new feature to the disease; I mean *infectiveness*. How this arises is a matter of speculation. To me it appears probable that, under a certain concurrence of conditions in and about the wound, a modification takes place in the vital endowments of the septic organism, whereby it acquires a parasitic habit, which enables it to breed in tissues of degraded vitality or even in the healthy tissues, and in this way to produce the infective endemic pyæmia which we sometimes witness in the wards of our large hospitals.[1] I shall develop this idea more fully by and bye.

Before leaving the subject of septicæmia, I may allude to the possibility of wounds being infected with septic organisms from within. As a rare occurrence, I am inclined to think that this is possible, and that it may account for the occasional alleged infection of protected wounds. From an observation by Chauveau, it may be inferred that septic organisms, when injected directly into the blood, are able to survive for two or three days, although unable to breed there.[2] It is conceivable that occasionally a septic germ entering the body in some of the ways which have been suggested may escape destruction and pass into the blood and lurk there awhile, and finding by chance some dead tissue or liquid within its reach, may multiply therein and produce septic effects. Such a contingency, if it ever occur, must be very rare, and would not appreciably detract from the value of the antiseptic mode of dressing wounds.

RELAPSING FEVER.—In 1872, Dr. Obermeier, of Berlin, discovered minute spiral organisms (spirilla) in the blood of patients suffering from relapsing fever. This discovery has been fully confirmed by subsequent observations. The organisms are found during the paroxysms; they disappear at the crisis; and are absent during the apyrexial periods.

These little parasites consist of spiral fibrils of the most extreme tenuity, varying in length from two to six times the breadth of a blood corpuscle. In the fresh state they move about actively in the blood. They have not been

[1] Such a modification or "variation" might be correlated with a modification of the ferment action, whereby a more virulent septic poison is produced. Would not such a view explain the sudden intensification of the infecting virus which was found by Chauveau and Dr. Sanderson in their experiments on infective inflammations?

[2] 'Comptes Rendus,' *1873, p. 1092.*

detected in any of the fluids or secretions of the body except the blood, nor in any other disease than relapsing fever. In form and botanical characters they are almost identical with the *Spirochaete plicatilis* of Ehrenberg (*Spirillum* of Dujardin), a species of bacteria found in dirty water and occasionally in the mucus of the mouth. Cohn designated the variety found in the blood *S. Obermeieri*, in honour of its discoverer.

In the beginning of the current year, Dr. Heydenreich[1] of St. Petersburg, published an elaborate monograph on this subject, which, I think, goes far to reconcile the conflicting statements and opinions put forth by previous writers in regard to the connection of the spirilla with relapsing fever. It is based on forty-six cases; these cases were studied with the most minute care; the blood was examined, and the temperature observed from two to six times each day. Altogether, over a thousand examinations of the blood were made.

Relapsing fever still prevails extensively in certain districts of Germany and Russia, but it is almost a forgotten disease in this country; and probably the majority of those in this room have never seen a case. It will, therefore, not be amiss if I remind my hearers, and myself, of its principal features. It is a contagious epidemic fever characterised by a sharp paroxysm of pyrexia, which lasts about a week, and ends with a severe critical sweating. This is succeeded by an intermission, also of about a week, during which the patient is apyrexial; then follows a second paroxysm, or relapse, which lasts four or five days, and ends, as before, in a critical sweating. Recovery usually follows the second paroxysm, but not unfrequently a third paroxysm occurs, and sometimes a fourth.

The paroxysms are occasionally broken by remission or pseudo-crises; and the apyrexial periods are sometimes interrupted by slight temporary rises of temperature.

Bearing these characteristics in mind, we shall be able to understand the significance of Heydenreich's observations. He found that every rise of temperature, whether that of the true paroxysm, or that following a pseudo-crisis, or those occurring during the intermissions, was invariably preceded by the appearance of spirilla in the blood. They disappeared entirely shortly before the crisis, and remained absent during defervescence and the subsequent apyrexial periods. During the whole of the main paroxysms spirilla were usually to be found in the blood, but their number varied in the most puzzling manner from day to day. One day they were abundant, the

[1] L. Heydenreich, 'Ueber den Parasiten des Rückfallstyphus,' Berlin, 1877. He gives a good *résumé* of the literature of the subject.

next day they were scanty, and the day after again abundant; they even varied at different hours of the same day; sometimes they vanished altogether for a time, and then reappeared in vast numbers a few hours later. Throughout these variations the temperature remained steadily high, or with only slight or moderate oscillations.

These discrepancies had been observed by previous inquirers, and had led some to doubt whether the spirilla had anything to do with the virus of relapsing fever; but a happy idea suggested itself to Heydenreich which seems capable of explaining them.

He found that when a little blood containing spirilla was abstracted from the patient and kept at the ordinary temperature of the room, the organisms lived in it for several days; but if the blood was placed in an incubator and maintained at the normal temperature of the body, they died in from twelve to twenty hours, and if the temperature was kept up to fever heat (104 deg. F.) their life was still shorter; they only survived from four to twelve hours. This led him to the conjecture that during the main paroxysm, not one, but several successive generations of spirilla were born and died before their final disappearance at the crisis. He surmised that in the usual course, the broods would overlap each other more or less, the new brood making its appearance before the last survivors of the old brood had passed away. This explained the variable number of spirilla found on different days and different hours of the same day. Sometimes the old brood would have altogether perished before the new brood reached maturity; this explained the occasional temporary absence of spirilla from the blood; it also explained the remissions or pseudo-crisis sometimes observed in the course of the paroxysms. So precise was the correspondence found to be between the appearance of the spirilla and a subsequent rise of temperature, that Heydenreich was able to predict with certainty, during the apyrexial periods, the approaching advent of a transient rise of temperature from the reappearance of spirilla in the blood, although at the time the patient presented no other indication of what was about to happen.

If these observations are to be relied on, and they appear to have been made with the most scrupulous care, we are led to the conclusion that the spirilla are the actual virus of relapsing fever.

The same conclusion is also strongly indicated by the results of inoculation experiments. Relapsing fever is easily communicated to a healthy person by inoculation with the

blood of a patient suffering from the disease. Experiments made in Russia on individuals who voluntarily submitted themselves to this practice, show that the blood is only infective during the paroxysms, but not at the crisis nor during the apyrexial periods. None of the fluids or secretions of the body except the blood are infective. All this shows that the virus is intimately associated with the spirilla, and is absent or present in exactly the same circumstances as the latter.[1]

The occasionally observed vanishing and reappearance of the spirilla during the paroxysm, without a possibility of new infection, seems to indicate that when the spirilla disappear they leave behind them something in the nature of seed or spores, from which the new brood springs forth. Ocular evidence of such germs is, however, still wanting. Several observers have noticed minute particles in the blood of relapsing fever which might pass for spores, and Heydenreich observed that some of the spirilla had a dotted appearance. But hitherto all efforts to cultivate the spores out of the body have failed, and their power of developing spores is more an inference than a demonstration.

Splenic Fever.—The first trustworthy observation of the presence of organic forms in an infective disease was made in splenic fever. This formidable disorder attacks sheep, cows, and horses, and is not unfrequently fatal to man. In 1855, Pollender discovered minute staff-shaped bacteria in the blood of splenic fever. This discovery was confirmed in a very extensive series of researches by Brauell, and has been corroborated by Davaine and other inquirers in France.

The bacterium of splenic fever is a short, straight, motionless rod, about as long as the breadth of a blood-corpuscle, and, so far as is known, it exists in no other form in the living body. It is found, besides the blood, in the spleen, in the lymphatic glands, and in some other tissues. That [illegible]m is the true virus of splenic fever has long been [illegible]nd the labours of Davaine, Bollinger, Tiegel, [illegible], most of all, of Koch, have removed the last [illegible] the subject. The work done by Koch is not only

[1] [illegible] paper by Motschutoffsky, in the 'Centralblatt für die Medicinis-[illegible]schaften,' 1876, p. 193. During the paroxysm the blood was [illegible] whether spirilla were detected in it or not. This agrees with [illegible]'s theory, that their occasional apparent absence during the [illegible] due to their being incompletely developed, or immature, and unrecognisable under the microscope.

valuable as a triumphant demonstration of a disputed pathological question, but is noteworthy as a model of patient, ingenious, and most exact pathological research.

We here come across an example of scientific prescience on the part of two distinguished men which is worth notice. It had been remarked by several observers that the contagium of splenic fever, as it existed in the blood, was comparatively short-lived and fugitive, but that, under some unexplained circumstances, the contagium was very persistent, and lurked for years in stables and other places where cattle were kept. Dr. Burdon Sanderson, writing in 1874, inferred from this circumstance that the organisms of splenic fever must have two states of existence; namely, that of the perishable bacteria found in the blood and some other more permanent form, like seeds or spores, in which they were capable of surviving for an indefinite period. In like manner, Professor Cohn, guided by the botanical characters of the rods found in the blood, classed them in that group of bacteria named by him *Bacillus;* and, as he had observed that all the *Bacilli* produced spores, he inferred that the *Bacillus anthracis*, for so he named the bacterium of splenic fever, would also be found to produce spores. These provisions were proved by the researches of Koch to be perfectly exact.

The following is a brief abstract of those points in these researches which chiefly concern us.

Koch found that mice were peculiarly susceptible to the virus of splenic fever. The minutest particle of the fresh blood or spleen of an infected animal infallibly produced the disease when brought into contact with the living tissues of the mouse. He found further that he could cultivate the organisms artificially outside the body. He proceeded in the following manner. He placed a speck of the spleen containing the rods on a glass slide in a drop of the blood-serum of the ox, or a drop of the aqueous humour of the eye of the same animal, and covered it with a piece of thin glass. He then placed the slide in an incubator maintained constantly at the temperature of the body, and examined the preparation from time to time under the microscope. In a couple of hours, he observed that the rods began to lengthen, and in a few hours to grow into long threads. These threads, after growing to twenty or a hundred times the length of the original rods, began by and by to assume a dotted appearance. The dots gradually increased in size and distinctness until, after the lapse of fifteen or twenty hours from the beginning of the experiment, they acquired the appearance of strongly refractive oval bodies, which were placed at

regular intervals along the threads. Finally, the threads broke down, and the oval bodies, which could be nothing else than spores, were set free and sank to the more depending parts of the drop. If the supply of nutriment were then exhausted, the process ended here, and the spores remained permanently unchanged; but, if additional nourishment were provided, the new spores were seen presently to elongate into rods, exactly resembling those originally existing in the blood or spleen. If the conditions were favorable, the new rods, after a period of rapid multiplication, in their turn entered on the formation of a new generation of threads and a new generation of spores.

The next point was to test the pathogenic activity of the rods and spores cultivated in this artificial manner. This was done by introducing minute quantities of the rods, or of the spores alone, into a small incision made in the skin of a mouse. Speedy death from splenic fever occurred in every instance. Koch found, without exception, that, if the tested material produced threads and spores in the incubator, it also produced splenic fever when inoculated into the mouse; and, on the contrary, if no such growth and development took place in the incubator, the tested material produced no effect when inoculated into the mouse. Proof could go no further: the infection absolutely followed the specific organism; it came with it, it went with it. These observations were repeated with the strictest precautions at the Physiological Institute at Breslau, under the eyes of Professor Cohn and other competent observers, who fully corroborated their exactness.

The variable duration of the activity of the contagium of splenic fever was now explained. Koch found that the rods had only a comparatively fugitive vitality; they lost their infective power generally in a few days; at the most, in about five weeks. But the spores retained their infective activity for an indefinite period, in spite of all kinds of maltreatment. They could be reduced to dust, wetted and dried repeatedly, kept in putrefying liquids for weeks, and yet, at the end of four years, they still displayed an undiminished virulence.

Cohn calls attention to the fact that the organism of splenic fever is identical in form and development with the *B. subtilis*. The only difference he could detect between them was, that the rods of *B. anthracis* are motionless, while those of *B. subtilis* exhibit movements. The figures you see before you might be indifferently labelled *B. subtilis* or *B. anthracis*, and yet one of these organisms is a harmless

saprophyte and the other a deadly contagium. We have likewise seen that the spirilla of splenic fever are morphologically similar with the *Spirochaete plicatilis*. We have further seen that there is ground for the assumption that the infective agent in contagious septicæmia is the common bacterium of putrefaction, but modified in such a way as to have become endowed with a heightened capacity for growing in the healthy tissues. Do not these remarkable coincidences point to a natural explanation of the origin of contagia? If contagia are organisms, they must necessarily possess the fundamental tendencies and attributes of all organised beings. Among the most important of these attributes is the capacity for "variation" or "sporting." Darwin brings forward strong grounds for the belief that variation in plants and animals is not the result of chance or caprice, but is the definite effect of definite (though often quite obscure) causes. I see no more difficulty in believing that the *B. anthracis* is a sport from the *B. subtilis* than in believing, as all botanists tell us, that the bitter almond is a sport from the sweet almond; the one a bland innocuous fruit, and the other containing the elements of a deadly poison.

The laws of variation seem to apply in a curiously exact manner to many of the phenomena of contagious diseases. One of these laws is the tendency of a variation, once produced, to become permanent, and to be transmitted ever after with perfect exactness from parent to offspring; another and controlling law is the tendency of a variation, after persisting a certain time, to revert once more (under altered conditions) to the original type. The sporting of the nectarine from the peach is known to many horticulturists. A peach-tree, after producing thousands and thousands of peach-buds, will, as a rare event and at rare intervals, produce a bud and branch which ever after bear only nectarines; and, conversely, a nectarine at long intervals, and as a rare event, will produce a branch which bears only peaches ever after. Does not this remind us of the occasional apparent sporting of diphtheria from scarlet fever? My friend Dr. Ransome, who has paid so much attention to the laws governing the spread of epidemics, relates the following instance:—A general outbreak of scarlet fever occurred at a large public school. One of the masters who took the infection exhibited diphtheritic patches on the throat. This patient was sent to his own home in Bowden. Six days after his arrival, his mother was attacked, not with scarlet fever, but with diphtheria; though there were no cases

of diphtheria at the time, neither at the school nor in Bowden.[1]

Take another illustration: cholera suddenly breaks out in some remote district in India, and spreads from that centre over half the globe. In three or four seasons, the epidemic dies away and ceases altogether from among them. A few years later, it reappears and spreads again, and disappears as before. Does not this look as if the cholera virus were an occasional sport from some Indian saprophyte, which by variation has acquired a parasitic habit, and, having run through countless generations, either dies out or reverts again to its original type? Similarly, typhoid fever might be explained as due to a variation from some common saprophyte of our stagnant pools or sewers, which, under certain conditions of its own surroundings, or certain conditions within the human body, acquires a parasitic habit. Having acquired this habit, it becomes a contagious virus, which is transmitted with its new habit through a certain number of generations; but finally, these conditions ceasing, it reverts again to its original non-parasitic type.

In regard to some contagia, such as smallpox and scarlet fever, it might be said that the variation was a very rare one, but also a very permanent one, with little or no tendency to reversion; while others, like erysipelas and typhoid fever, were frequent sports, with a more decided tendency to reversion to the original type. In regard to some pathogenic organisms, it might be assumed that the parent type had disappeared, and the parasitic variety only remained, just as the wild parents of many of our cultivated flowers and vegetables have disappeared, leaving behind them only their altered descendants.

How aptly, too, this view explains what used to be called the "Epidemic Constitution," and the hybrid forms and subvarieties of eruptive and other fevers.

I must not pursue this vein further. I have said enough to indicate that this conception enables us, if it does nothing else, to have coherent ideas about the origin and the spread of zymotic diseases.

In applying the doctrine of pathogenic organisms, or *pathophytes*, as they might be termed, to the explanation of the phenomena of infective diseases, we must be on our guard against hard-and-fast lines of interpretation. So far as

[1] Complex cases of mingled scarlet fever and diphtheria are sometimes seen. Similarly the peach-tree will occasionally, among a multitude of ordinary fruit, produce one fruit of which one half has the peach character and the other half the nectarine character.—*Darwin.*

our very limited knowledge now extends, the pathophytes hitherto discovered all belong to that group of the fungi which are called bacteria. Now, fungi have two marked characteristics, namely, the tendency to assume the parasitic habit, and the possession by some of them of a special ferment action. Both these characteristics may bear a part in the action of pathogenic organisms. In the complex phenomena of septicæmia such would appear to be the case; a poisonous ferment-product first intoxicates the system, and then the organisms themselves prey upon the dead or moribund tissues.

There is, as Dr. B. Sanderson has pointed out, a marked distinction to be drawn between those common processes of infective inflammation which are shared in by animals generally, such as septo-pyæmia, erysipelas, and the diphtheritic process, and those specific contagia which are strictly confined, like ordinary parasites, to particular species. There is nothing in all nature more wonderful than the intimate and subtle nexus which unites a parasite to its host. A hundred examples might be given. Even different varieties or races of the same species have different and exclusive parasites. It would seem as if this nexus depended on some delicate shade, a *nuance*, something like an odour, or a savour, or a colour, rather than on differences of structure or chemical composition. The same minute correlation is seen in specific contagia—all are strictly confined to one or a few species. Vaccinia is confined to man, the horse, and the cow; scarlet fever is confined to man, and perhaps the swine; most of our specific diseases are absolutely confined to man. The human and ovine smallpox, although so wonderfully similar, are not intercommunicable. I am, therefore, inclined to believe that, in regard to specific contagia, we shall find more guiding analogies in parasitism than in fermentation. Our information at present is, however, so defective that it is not wise to enter into furthur speculations on this subject.

Gentlemen, I have brought my task to a conclusion. I believe that the doctrine of a contagium vivum is established on a solid foundation; and that the principle it involves, if firmly grasped in capable hands, will prove a powerful instrument of future discoveries. And let no man doubt that such discoveries will lead to incalculable benefits to the human race; our business in life is to do battle with disease, and we may rest assured that the more we know of our enemy the more successfully we shall be able to combat him.

Résumé *of* Recent Contributions *to our* Knowledge *of* "Freshwater Rhizopoda." Part IV. Compiled by Wm. Archer, F.R.S. (With Plate XXI.)

Rhizopoda Monothalamia Monostomata.

Euglypha tincta, n. s., Archer.[1]

The minute form which I have named above is well distinguished by its reddish colour; every other Euglypha is colourless. It is true it may be said to be "colourless" when young (like *Arcella vulgaris*), but it is rare to meet with an example absolutely so; there is nearly always some amount of tint, be it only of a slightly purplish character; old examples are red or brownish, as highly coloured, in fact, as the test of *Arcella vulgaris*. The test is minute, but somewhat varying in size (as, indeed, do all the species), ovoid, compressed, reddish, near the opening often somewhat paler; hexagonal facets *extremely minute*, elongate; test not produced into any elongate "neck," its opening bordered by indistinct "teeth," but usually indefinitely terminated, giving an, as it were, torn aspect to the margin (as I said at the Club meeting, as if "unfinished" round the mouth); no spines; the body-mass characteristically Euglyphan, nucleus (with nucleolus) large, the usual zone of darkish granules across the middle. The pseudopodia are seemingly more numerous than in other Euglyphæ, less fitful, that is, more slowly projected or altered in position or arrangement; they seem to form a tolerably steadily displayed tuft; though, on the other hand, one may often search long to find an example with pseudopodia projected at all. One far more frequently meets with abandoned tests than with those still in a living state. The small size, the very minute facets, the ovate compressed form of the test, with its irregularly bordered opening, and, above all, the purplish, reddish, brick-red, or brownish colour, very well distinguish this form, which I find not to be very uncommon in certain situations. I have taken it in the east and west of Ireland and in Scotland.

Since the above was written I have for the first time seen Professor Bailey's communications.[2] I find it is extremely probable that that observer has the priority, and that his *Euglypha brunnea* may be truly identical with that described above.

I am very glad to find that Bailey has taken the correct

[1] "Minutes of Dubl. Micr. Club" in this Journal, vol. xvi, n. s., p. 107.
[2] 'Proc. Acad. of Nat. Sci.,' Philadelphia.

step in forming his genus Nebela as distinguished from Difflugia, and I look forward with much interest to his forthcoming work on these beings at large.

Troglodytes zoster, Gabriel[1] (Pl. XXI, figs. 1—7).

Under the above name the author describes a form which appears (as could seem obvious on comparison of the figures) to belong to the same genus at least, if it be not indeed specifically identical with *Chlamydophrys stercorea*, Cienkowski. This latter, as before mentioned, might seemingly properly be referred to the genus Platoum, Eilh. Schulze. The form now in question is found too in a similar kind of habitat to Cienkowski's—in earth permeated by animal excrement. If this conjecture be correct the name Troglodytes would fall to the ground.

But the author gives at considerable length his observations on the development of the form, which, although his views may be fonnd open to objection, are very interesting.

He attributes to the "conjugation" a special significance and importance as the primary or introductory generative act.

Two forms meet by their frontal apertures (in the well-known way), their pseudopodia become gradually drawn in, and the outlying protoplasm becomes fused and form a yellowish cylindrical mass between the two so conjoined individuals. From this latter there are given off numerous minute acute granuleless processes, forming a kind of superficial piloe covering (fig. 1). In about half an hour and by degrees the intermediate mass becomes smaller, the minute processes disappear, a line of demarcation presents itself, and the two animals become removed a little from one another; the connecting sarcode parts, and the conjugative act is over. They now appear, as it were, more lazy; their movements less active, their pseudopodia less extended. On the other hand, the dispersion of the median granular zone internally goes on with shorter and shorter pauses, this state lastly for probably several days. The hyaline homogeneous body-substance, especially of the posterior zone, becomes pale, the mass cloudy, and the demarcation of the zones obliterated. The contractile vacuole becomes reduced in activity and size. The nucleus and nucleolus, however, remain unaltered. The author, indeed, avers it does not at

[1] B. Gabriel: "Untersuchungen über Morphologie, Zeugung und Entwickelung der Protozoen;" i.: "Der Entwickelungscyclus von *Troglodytes zoster*" in C. Gegenbaur's 'Morphologisches Jahrbuch,' Bd. i, p. 535, t. xx.

any time take a share in the development of the germ, maintaining throughout its integrity. Hence he holds that this body cannot at all be regarded as a sexual gland in the sense of Claparède and Lachmann, but only as an organ of secretion ("ein besonderen Secretionsvorgängen dienendes Gebilde"). The next following changes concern the median zone alone; its granules become pretty regularly scattered through and through the body-mass, the total body-substance changes to a dirty-yellow, cloudy mass, the nucleus the only unaltered element. By-and-by, however, a renewed activity sets in; a number of extremely minute granules appear at the borders of the body-mass, which are seen in dancing agitated motion—taken at first by the author for molecular—these, in an hour to an hour and a half, break away in innumerable multitudes and swim rapidly about in a "tumultuous" manner. These the author calls "Befruchtungskörperchen." Soon now the nucleus disappears; whether it becomes atrophied, or mixes its contents with the rest of the mass, the author leaves in abeyance. These minute bodies by-and-by disappear. Now, there is seen within the still intact test a remaining mass, very capable of being overlooked as a mere portion of detritus undergoing solution, and, therefore, of no further moment; but this is the germinal mass, and not at all defunct, but endowed with latent life. Simultaneously arising at several points of this mass there are now seen minute sharply, contoured puncta, soon increasing in size and appearing as little elevations. These are the germs; they show a very equable distribution, mostly in lines, not crowded. These little papillæ the author compares to "shagreen-paper," and for want of a better term would call this the "shagreen" state. At first occupying the whole cavity of the test, it becomes afterwards balled together, leaving at the oral pole a little half-moon-shaped vacuity. Soon the test now begins to split and break up, till at last the "shagreen" becomes free; it loses now its rounded form, presenting an irregularly bounded, not very refractive body; its surface appearing rough owing to the projecting granules, a throughout characteristic speciality. It now undergoes a process of cleavage, but this is not regular either in direction of the lines of cleavage or in the size or form of the divisions, which, when completed, form an unconnected cluster (fig. 2). The basic substance in which the sharply contoured granules lie embedded disappears, the whole breaks up into a finely granular detritus, producing a complete setting free of the granules. These increase in size, are sometimes round,

sometimes elliptic, or with a concavity at one side, of a pale blue colour and refractive; they are the germs or germinal bodies. Slight movements of these are noticeable, consisting of turnings on the longitudinal axis (fig. 3).

The further development of these germs becomes first rendered evident by the appearance of a minute, pale rose-coloured refractive spot at both poles, the first vacuole, which, even to the final development of the form, but seldom collapses. In order to distinguish these from the subsequent larger contractile vacuoles the author gives them the name of "stigma"; he hence names the first state of the development the monostigma-form (fig. 4). He was long in doubt as to the subsequent mode of development, until he saw two "germs" *become mutually fused* (fig. 4); they lie alongside, a process from one seems to pass into a depression in the other, a fusion ultimately takes place by the two opposite poles at one end—the conjugation poles—(without exception the larger and greater in mass), becoming inosculated, the other poles remaining with stigma persistent, named the stigma-poles, and remaining as distinct lobes of conical form with an intervening narrow sinus. The product of this zygosis is the second state of the development of the germ, and represents the diplostigma-form (fig. 5). These are non-nucleated protoplasmic masses; with this partial fusion a new activity is imparted; a single one would seem not capable to grow into the final form—a new Troglodytes.

The first indication of the origin of a nucleus coincides with a grouping of the increasing granules, which at first generally distributed, by degrees become more massed in the middle zone; soon thereupon a separation of the cluster of granules ensues, leaving a median contourless whitish spot, the optical expression for a fluid-drop; this now becomes circumscribed by a delicate line, and the same time retreats backwards from the stigma-pole (fig. 6). Simultaneously with the commencement of change of place of the probably still thick-fluid nucleus, a further alteration of the grouping of the granules takes place gradually, collecting towards the middle, and by degrees, in fact, forming the "girdle;" the nucleus, arrived at its normal place, becomes by degrees consolidated, its nucleolus recognisable, and its development finished.

The narrow sinus separating the lobes of the conjugated body by degrees disappears, their boundary becomes the limit of the oral zone of the young Troglodytes; the stigmata seem to remain whilst the pulsating vacuoles make their appearance in their place just behind the median granular zone.

The first indication of *test* is the appearance of a clear border around the body, as it were, hardening by degrees into an, at first, extremely delicate line, by-and-by assuming its double contour (fig. 7).

Taking a momentary review of the stages (here so briefly disposed of) as described at great length by the author, I fancy the more general conclusion would be to regard, not the "conjugation," not the presence or the presumed operation of the so-called "Befruchtungskörperchen"—as the indication or expression of a sexual reproduction—but rather, if any of the described processes is to be so interpreted, it must be the conjugation of the "germs" of two individuals, the "monostigmatic form" so as to produce the "diplostigmatic," which grows into a new representative of the species. This seems very fairly comparable to the conjugation of zoospores of Algæ.

As to the identity of this form it really appears, as mentioned, to be one and the same with *Chlamydophrys stercorea*, Cienk. (1875) as will be, I fancy, sufficiently readily seen on comparing all the figures (in orig.), or, indeed, even these here repeated. If that be so the name *Troglodytes zoster* (1876) would fall to the ground. In fact, Chlamydophrys as a genus may turn out to be coincident with Platoum, E. Schulze.

Cochliopodium pellucidum et *C. pilosum*, Hertwig et Lesser, = *Amphizonella vestita*, Archer.

Whilst I long since discovered my own errors of interpretation in respect to the form I first recorded, referring it then to Amphinozella, Greeff, under the name of *A. vestita*, I am none the less convinced that, so far as our knowledge goes, only one species exists referable to the restricted genus so well described by Hertwig and Lesser under the name of Cochliopodium. I feel pretty well satisfied that not only the green (chlorophyll-bearing) and the colourless form are one and the same, but that even the pilose condition cannot be regarded as specifically distinct from either. Although the latter was the first form I had seen, it is really by far the most rare, the colourless non-chlorophylliferous being the most frequent. I have, a few summers ago, taken gatherings in which the three forms occurred commingled, and showing every possible intermediate state between the extremes as regards the characteristics in question. Sometimes the hair-like processes were in length not far from ⅓ of the diameter of the body, and of all lengths down to an almost imperceptible pile, finally wholly absent. Sometimes the examples were densely loaded with a layer of chlorophyll-

granules, sometimes with only a few, and sometimes these were absent. Hence, surely, according to the laws of priority the name of the rhizopod should stand as *Cochliopodium vestitum* (Archer), Hertwig et Lesser. Notwithstanding, then, as I believe, the unity of the forms, I feel satisfied, with Hertwig, that "*Cochliopodium vestitum*" not only specifically distinct from every other rhizopod, but that a special genus is necessary for it.

And although a distinct genus is doubtless necessary, my referring the form to Amphizonella was probably a more pardonable error than the one more frequent, that of making too many genera. But my great error was in the interpretation of the *halo* often seen around the form; this is not due, as I at first thought, to the temporary pouring forth through the outer envelope of a pellucid sarcode, but to the occasional eversion through the frontal free opening of so much of the sarcode-body (as first correctly pointed out by Hertwig and Lesser), as forms a flattened base projecting beyond the edge (formed by the double contoured envelope, which, although flexible, is somewhat comparable to that of Arcella), and on which projecting portion of the body-mass the rhizopod stands or moves (by its contractility), the whole somewhat comparable to the "foot" of a mollusc, and by which it sometimes sticks to the slide in one and the same place with a considerable tenacity, even upon force applied to effect its removal.

Whilst this envelope (not to call it a test) is quite flexible, following any change of figure of the body-mass, and assuming an expanded shape at the vacant opening for emission of pseudopoda, Hertwig and Lesser deny that the pseudopodia have the power to become projected through it at any other point. But their concluding paragraph on this form, and the figure they there refer to,[1] seem, taken together, to show they must have really observed this phenomenon, which is probably very rare. It cannot be doubted that the figure referred to represents a Cochliopodium, and probably only a small form of one and the same species, which occurs of very varied sizes, some very minute, the latter presumably young examples. There are there shown three places (for the third must be behind to account for the pseudopodia seen to the left), whence pseudopodial stems emanate. (See our Plate XXI, fig. 8).

These authors have not met with the green form described by me. There cannot be a doubt, I venture to hold, but that the chlorophyll-granules, when present, just as much

[1] Loc. cit., Bd. x, Suppl., t. ii, f. viii, A.

belong to the organisation of the species as do the same in any other habitually chlorophyll-bearing form, such an *Acanthocystis turfacea*, *Raphidiophrys viridis*, &c., and are not at all merely due to incepted food of algal nature.

The place of this form may probably be beside Arcella; as to the flexibility of the test, that characteristic is possessed by the test of Pseudochlamys. The pseudopodia, however, are thin and slender, terete and pointed, but, as is well known, those of Arcella are much more like those of Difflugia. Still, Hertwig and Lesser are more inclined to keep their genus apart from Monothalamia, on account of the great mobility of the body-form.

A pretty similar account of this form is likewise given by Eilhard Schulze.[1] This author does not concur in the opinion that pseudopodia can at any time be protruded through the investing coat, but that such may not, at least sometimes, take place seems to be contradicted by Hertwig and Lesser's figure already cited.[2] Schulze also corrects my error as to the seeming envelope of sarcode matter, which (as mentioned) is, in fact, only the broadened out "oral" part of the structure. Schulze has not found the pilose form; he regards the chlorophyll-granules sometimes seen as due to incepted (algal) food. As mentioned, I cannot concur in this view.

Rhizopoda Monothalamia amphistomata.

Ditrema flavum, n. s., Archer (Pl. XXI, fig. 9).

About the size of *Amphitrema Wrightianum*, this pretty, and though seemingly widely diffused, still very rare rhizopod, is quite different in form and colour therefrom, whilst it must be held as essentially (generically) distinct, the test being a pure secretion-product, the form repudiating any employment of foreign particles in its construction. It is compressed, broadly elliptic in the broad or usual view. The opposite sides in this view for a time parallel or gently concave at the middle, becoming gradually merged in the broadly rounded ends, in each of which occurs a rounded very sharply bordered "mouth," a slight rim projecting inwardly, the whole looking as it were like a perforation cleanly and sharply "drilled" through. The test is of a yellow colour, the margins of the opposite apical openings approaching to a reddish tint (probably because they are somewhat thicker).

[1] E. Schulze: "Rhizopodstudien" in Schultze's 'Archiv f. Mikr. Anat.,' Bd. xi, p. 337, t. xix, f. 1—5.

[2] Loc. cit., t. ii, f. viii, A. (See our reproduction thereof, fig. 8.)

its surface glossy, its substance thick and membranous, structureless. In side or edge view the test is narrow-oblong, and the margins (outline of the frontal surfaces) nearly straight and parallel. The body, like that of *Amphitrema Wrightianum*, is loaded with chlorophyll-granules, though in the few specimens only which I have seen, not so densely so as in that species, and it carries a median nucleus. The pseudopodia, issuing from each pole, form a dense tuft, are linear, scarcely granular or ramifying, steadily displayed, and reach about one half the length of the test. They are, on the whole, like those of *A. Wrightianum*. As in that species body does not fill the test, and indeed does not seem to be in contact with it anywhere, except at the borders of each of the apical openings.

Sarcodina nuda.

Pelomyxa palustris (Pelobius, olim), Greeff[1] (figs. 10—15), is a very large form, a single example attaining sometimes even over two millemètres in diameter. When first placed on a slide its outline is generally round or but slightly lobed, and of course flattened between it and the covering glass. Carefully viewed, after a little pause the observer sees its pellucid margin pushed off in wave-like lobes or hemispherical and even finger-like projections, and surrounding a dark brown body-mass (fig. 10). Here a process is withdrawn, there another projected, and these may even assume a filiform character arranged in tufts (somewhat like the villous patch of *Amœba villosa*). This play kept up for some time, a wave-like motion begins in the interior, and abruptly at any place a broader process breaks forth outwardly, into which, as into a sac, a mass of contents is poured, forming a broad pseudopodium, and so the form performs its locomotion, a second and third similar process following thereon; thus what looked on being placed on the slide like a mere little ball of mud, has now acquired a much-lobed figure, as it glides with its expansive amœboid movements.

More closely examining the contents, it is seen that the dark colour and almost complete opacity are due to the presence of dark and opaque substances immersed in a completely colourless body-substance, these substances being made up of all sorts of foreign bodies incepted, diatoms, algæ, Arcella- and Difflugia-tests, entomostraca, and above all, a considerable quantity of mud and sand-particles. Those examples which are the least loaded with these

[1] Greeff: Schultze's 'Archiv,' Bd. x, p. 51, t. iii, iv, v.

foreign bodies are, of course, those best suited for examination (fig. 11).

In such, even under a moderate power, a great number of *shining bodies* ("Glanzkörper") of roundish or oval figure can be seen, to be mentioned again.

Viewed under a higher amplification, it can be seen that the body-substance is made up of two elements—(1) a completely hyaline and homogeneous substance, chiefly external, and (2) an inner one of vesicular nature.

As regards the hyaline outer substance, it surrounds the whole body, as has been mentioned, forming a narrow zone, giving off the above-mentioned amœboid processes, and into which the contents flow, as into a sac.

The second substance of the body occupies almost the whole of the interior, and consists of larger or smaller closely-packed vesicular spaces, lying in a hyaline, richly granular, intervening substance, the whole not unlike *Actinosphærium Eichhornii*, but not so regular or compact. In Pelomyxa there is no differentiation of outer or inner stratum, nor are the spaces so equal in size, but large, small, and very small lie side by side. A pushing about and alteration of their position besides takes place, especially in the interior, less more outwardly, owing to the amœboid movements of the animal (fig. 11).

These vesicles represent isolated unconnected spaces; sometimes two or more can be seen flowing with the stream into one of the lobes; they readily become detached from the rest and flow, like other "contents," thereinto. These spaces are few in young examples, and they are diminished in number in those which have become densely packed with foreign bodies.

Touching the mutual relations of these two elements the author propounds the queries :—(1) "Are these clear spaces formed like true vesicles, with special walls? (2) what contents have these vesicular spaces? and (3) of what nature is the granular intervening substance in which they lie, that is, their peculiar matrix or basic substance?"

As regards the first query, the author replies, the spaces are without special wall, they are simple vacuities or hollow cavities in its substance. As to the second query, their contents must be of a different nature from the surrounding substance, since both stand side by side without any commingling. The contents are pellucid. Under the highest amplification no further form-elements can be perceived, except here and there, not in all, a few dark shining granules. That the contents must be of a fluid nature is evi-

denced by the vigorously tremulous, or dancing movement of these granules, that is to say, a distinctly expressed molecular movement. In this Pelomyxa agrees with Actinosphærium and other vacuole-bearing Sarcodina. The author thinks this fluid must be simply water.

Coming to the third question, the intervening substance must be regarded as the real basic substance of the whole inner space, and merely interrupted by the vacuoles. It is hyaline, but filled with a great quantity of granules, some dark-shining and large, others clearer and more minute, even down to the finest puncta. This basic substance is further the matrix for all the other structures to be mentioned, and is the vehicle inclosing the food, &c.

The body-mass thus is seen to consist of pure protoplasm composed of two strata, an outer cortical one and an inner parenchyme. The former is hyaline and homogeneous. It is the chief seat of contractility, and hence in it the locomotive power resides. The whole inner parenchyme is of thinner consistence, and is but passively moved; it is richly granular and filled with watery vacuoles, often so crowded that the substance appears reticulately interrupted. The two strata are not sharply marked off, but pass off gradually into one another.

In the so composed body-mass there occur further three structures—(1) the nuclei; (2) hyaline and homogeneous bodies of roundish, ovoid, or irregular figure, of glassy appearance (the "Glanzkörper" of the author); and (3) fine bacilliform bodies.

The occurrence of the nuclei in considerable numbers becomes in so far a principal character for Pelomyxa. They lie in the inner space, irregularly distributed between the vacuoles, more numerously in the middle of the body, more sparingly outwardly (fig, 11). In examples, say one millimèter, in diameter, there may be some hundreds. They are delicately-walled bodies of globular, more rarely oval, figure, as a mean about 0·012 millimètres in diameter, with hyaline contents, pervaded more or less by dark granules. Their position, form, and appearance, give in all respects the indubitable impression of cell-nuclei. Acetic acid and alkalies do not cause any coagulation, but a solution of the contents. Alcohol causes a coagulation of the contents, which become darker. Tincture of iodine produces the same effect, at the same time the contents becoming dark brown. The author sometimes thought he recognised a second inner contour—a nucleolus—but only rarely, and at best but indistinctly.

In the living state he sometimes recognised noteworthy alterations. In place of the firmer or coarser, darkly-shining granules in the inner space, these not distinguishable from those in the protoplasma, he noticed to occur a number of large structures. These were roundish, sharply contoured, by-and-by with a punctiform centre. This centre enlarges, along with the body itself and shows itself as a cavity, apparently filled with a hyaline substance; they then have the appearance of nuclei with comparatively large nucleoli, or they might be taken for cells with several nuclei (fig. 12). These "nuclei of the nuclei" (Kern-Kerne) grow considerably, the inner cavity of the nucleus at the same time expanding, until at last it bursts, the "nucleus brood" passing out into the parenchyme of the Pelomyxa (fig. 12). Here the inner cavity becomes more and more expanded, so that finally the outer peripheral layer disappears, and then only a simple, sharply contoured, hyaline, and shining body of round figure has originated from it. This the author holds to be the origin of the second class of bodies above mentioned—the "Glanzkörper"—and which are, he thinks, probably to be regarded as the zoospores.

These bodies, like the nuclei, but in still greater numbers, are scattered in the inner parenchyme (fig, 11). They are mostly globular, many also are oval, pyriform, or more rarely irregular, even hollowed, lobed, or furrowed. The smallest have a diameter of about 0·006 mm., the largest over 0·06 mm., the mean size, about 0·02—0·03 mm., being, however, by far the most numerous. They consist of a solid shining capsule, and usually completely hyaline and homogeneous contents. Dilute acetic acid has little effect, but under concentrated acid the peculiar shining appearance sooner or later disappears, they lose their firm appearance and collapse, and their contents become as if granulate. Alcohol produces the same result. Iodine colours them intensively brown. Sulphuric acid completely dissolves them.

Although the author is most given to the opinion that these bodies originate from the nuclei, as above mentioned, he sometimes thought that they might originate direct from the protoplasm, since he frequently saw these scattered in numbers through the protoplasm, the nuclei around at the same time perfectly unaltered.

These bodies increase in the interior of the Pelomyxa by means of *division*. They are found biscuit-shaped, more and more constricted, and the portions on the point of separating, such divisions, however, not always dividing the body into equal halves, but sometimes only a small portion being cut

off in the form of a bud. The division takes place along with the capsule, not merely inside it.

The author sometimes noticed in some of the largest of these bodies delicate outlines of an irregular figure, as if the contents had partially receded from the wall; in other words, as if a certain amount of amœboid movement of the contents had taken place. He sometimes, too, thought he had seen the delicate outline of a nucleus. He could see no further development of these bodies. It is probable they are expelled at a certain stage of maturity.

On one occasion the author placed an apparently defunct example under the microscope; it showed, in fact, a rugged, almost crumbling appearance, manifestly near a break up. But he was surprised to see a remarkable spectacle. Around the whole outer margin of the Pelomyxa there came forth an incalculable number of minute "Amœbæ" surrounding the mother-body in a thick, annularly arranged crowd. These showed all the same habit, movements, and size. Each showed a nucleus with nucleolus, and a contractile vesicle, the latter mostly quite posterior (fig. 13). After its distinctly perceptible contraction several minute vesicles made their appearance in the same place; these gradually uniting, reproduced the single vesicle of the original size. In about half an hour their movements became weaker and slower. In place of the vigorous amœboid contractions of the whole body, merely single hyaline lobes or finger-like processes were extended (fig. 14); as they contracted one by one into a globular or pyriform figure, a resting state set in. Then a long vibrating filament was projected from the body, and so the metamorphosis of the Amœba into a flagellate form was completed (fig. 15). After some rapid rotating movement the author could not any further follow out their fate.

The question arises whether these little Amœbæ really represented a development state of the Pelomyxa, and, further, whether these originated from the shining bodies (Glanzkörper).

The fact of the Amœbæ issuing under the author's eyes from the Pelomyxa-body, and in such great quantities, he thinks, shuts out the idea that they were foreign or parasitic bodies, whose germs had been merely previously incepted. As to the second point, he likewise thinks there could have been no other origin further than the shining bodies. In the interior of the Pelomyxa example there occurred very few of these in the normal state, but, on the other hand, many paler bodies, which looked like their empty and collapsed capsules.

The third special constituent of the contents of this remarkable sarcodine, Pelomyxa, are the bacillar bodies. Besides the nuclei and the shining bodies occur in the parenchyma innumerable quantities of fine hyaline bacillar bodies, of greater or less length, but in general very short, in the mean not over 0·006—0·008 mm. in length. They lie, like the other structures, free between the vacuoles, and become, like them, moved about by the amœboid movements of the Pelomyxa (fig. 11). Sometimes they surround the shining bodies so closely that the author fancied they took their origin therefrom. Their surface is smooth and contents perfectly hyaline. The author sometimes thought there was a longitudinal canal in their interior, as well as a transverse striatum; but he could not satisfy himself of either.

These bodies consist of organic substance, as shown by their behaviour in presence of reagents. Removed from the body they show a dancing, that is, molecular, movement. The author could make out nothing of the significance of these bodies.

This curious sarcodine has been found near London by Professor Ray Lankester. It has not turned up anywhere else in the United Kingdom, though it probably must occur with us in similar situations.

Hyalodiscus rubicundus, Hertwig et Lesser[1] (fig. 16).

The form so designated as the type of a new genus is distinguished from any known Sarcodina by the peculiar method of its locomotion. Unlike other naked forms, this is not effected by means of pseudopodia, nor by a stream of protoplasm forwards, into lobes of the body projected anteriorly, but the movement affects all points of the surface alike, and only the direction in which the individual parts of the superficies move determines that in which the whole organism glides onwards.

An example seen under a moderate power appears as an oval body of a brick-red, reddish-brown, or greenish-brown appearance gliding along. Under a higher power this can be seen to form only the reddish middle portion surrounded by a colourless and hyaline border. Then the object appears as a colourless disc with a granular coloured mass imbedded, usually occupying the median portion of the disc, but sometimes more towards the posterior ends. This margin is found to be homogeneous and structureless, and it is with difficulty seen, whilst the coloured median region is seen to be more or less sharply marked off therefrom. Besides

[1] Loc. cit., p. 49, t. ii, fig. v.

the pale-bluish granules of every granular plasma, occur the here characteristic ones; this central substance further shows a greater or less number of irregularly oval-figured bodies, varying from a greenish-brown to a reddish-brown tint. These the authors regard as manifestly more or less assimilated food-substances of vegetable origin, becoming more and more reddish the more they have become digested. This coloured region further possesses a number of vacuoles, sometimes difficult to be made out owing to the opacity of the body-substance. The authors were unable to determine if these were contractile, an observation, indeed, rendered the more difficult owing to the constant rolling movement of the organism, causing a vacuole brought under view to be the next moment withdrawn from observation.

The general opacity of the form rendered a critical examination of the nucleus impossible, but the presence of this body, of ordinary character, was rendered evident by application of acetic acid and subsequent pressure.

The foregoing curtailed description applies to the ordinary, that is, the flat, view of the organism as obtained from above. The authors sometimes succeeded in obtaining a profile view as it crept along the surrounding objects. They were then able to see that the lower part of the animal, sometimes smooth, sometimes bent, adapted itself to the conditions of the surface on which it moved, whilst the, so to call it, dorsal side formed a hump-like elevation. This elevation is formed of the coloured granules, and, according to their position, as seen from above, it appears sometimes median and sometimes at the hinder end. Sometimes this elevation is steep, explaining why sometimes the median region, as seen from above, appears so sharply marked off from the hyaline border. This latter, in this side view, is seen to encompass the organism above and below.

The most remarkable, and also characteristic, feature of this form is its mode of locomotion. Still less than in an Amœba this is effected without the aid of pseudopodia; only a very slight alteration of contour, with the slightest possible wave-like expansions occur, too slight, the authors think, to account for the movement of this sarcodine. By the application of higher powers the authors made out that the progression was effected by a revolution or rolling movement of the whole body, so that each point of the superficies comes to be in a constant rotation, by virtue of which it advances from the posterior end forwards to the anterior, and then to the "ventral," and so on, like a wheel. This action can be the more readily seen by watching certain

foreign bodies, such as bacteria, frequently attached to the superficies of the sarcodine, as they are passively carried onwards. This rotation is not confined to the outer layer, the whole body-mass partakes of it; by focussing-in, they could see that each granule described its circuit, the nucleus, though nearly central, making its comparatively short excursions, sharing, as it must, in the rotating movement of the whole body-mass.

This interesting kind of protoplasmic movement, the authors think, can be explained only by assuming that every point of the body possesses a nearly equal amount of contractility, as Max Schultze did to explain the protoplasmic current. Were there a passively moved endosarc and an actively moving ectosarc, the former could be only mechanically set in motion by the latter, its energy getting gradually lost inwards and absolutely ceasing at the middle. But here this is not the case, as there is no difference perceptible in the rate of movement of the inner and outer portions.

Rolling thus onwards this sarcodine but little alters its general figure, and that only from more or less of an oval to round, its upper elevation the while more or less steep or depressed. An alteration of the direction of movement is brought about by an alteration of the direction in which the body-parts rotate.

The authors did not directly observe the inception of food, which must become simply pressed inwards as the organism glides onwards.

Its size is very variable, its longitudinal diameter being from 0·03—0·06 millimètres.

Dactylosphærium vitreum, Hertwig et Lesser,[1] (figs. 17, 18)

Under the foregoing common name, the authors, *ad interim*, combine two forms, agreeing indeed in their main characters, but still showing some constant differences, and therefore probably, in reality, distinct species. Both possess an irregularly rounded figure, from about ·06 to ·012 millimètres in diameter. The protoplasm is hyaline, containing immersed therein a great number of variously sized, coloured, strongly refractive granules. In one of the forms these are constantly of a bright clear yellow, in the other constantly green, these differences accompanied by other minor ones proper to each. These coloured elements are crowded and fill the body-mass all but a narrow hyaline border; so crowded are these that the authors were unable to

[1] Loc. cit., p. 54, t. ii, fig. 1, A and B.

perceive a nucleus, but they noticed in the yellow form several contractile granules.

From the body radiate everywhere around the broad, blunt, slightly conical, pseudopodia, in length reaching about a half of the body-diameter, and like the border, they consist of a perfectly homogeneous, quite clear, glassy-looking, plasma. In most, if not all, of the examples of the green form the whole superficies (including the pseudopodia), was covered by peculiar protoplasmic, hair-like prolongations, resembling the partial one of Amœbæ, but not the same; no movement was perceptible in these minute villi. Very peculiar is the mode of retraction of the pseudopodia: one about to become drawn in abruptly alters its figure—its usually smooth surface becomes uneven and irregularly hollowed out here and there—whereupon it quickly flows back into the body-mass. The whole process conveys the impression as if the pseudopodium had suddenly lost its turgidity.

A further distinction between the two forms is seen in the mode of motion. The green animals lay mostly at rest as more or less regular balls, and only these, with their not numerously projected pseudopodia, showed a slow forward or backward movement. It was quite different with the yellow animals. These not only moved with comparative rapidity by aid of their quickly projected, mostly numerous pseudopodia, but even their body-mass took an active share in locomotion, similarly to that of Amœba. In this form the authors saw a division and separation into two of a single individual.

The authors suggest the possibility that their green form might be one and the same thing with the form described as a variety of *Amœba radiosa*, by Auerbach.[1] But the fact that in that form the granulated contents, completely filling the body-mass up to the very margin, and passing even into the pseudopodia, is regarded by the authors as speaking very strongly against the identity of that with this form, in which latter, such never takes place.

Leptophrys cinera (fig. 19), *L. elegans*, Hertwig et Lesser (fig. 20).

The forms for which the authors establish a genus under the above name belong indeed to the most delicate-looking of Sarcodina. Their protoplasm is very pellucid, thickly permeated with vacuoles of small and nearly equal size, and non-contractile; the interspaces are filled with very minute

[1] Auerbach: "Ueber die Enizelligkeit der Amœben" in 'Zeits. f. Wiss. Zool.,' Bd. vii, p. 401.

granules, almost looking like minute pearls. The authors noticed the presence of a nucleus but seldom, still, indeed, in the example under observation, three nuclei were present; they possess a central bluish nucleolus. The pseudopodia are slender, pointed, free from granules, and unbranched; they are not equally distributed over the body-surface, but rather confined to the extremities of the lobe-like extensions of the body; at these places they often take origin from a homogeneous protoplasm, free from granules and vacuoles.

The locomotion is effected by the conjoint action of these amœboid protoplasmic processes and of the pointed pseudopodia emanating from them. This takes place pretty actively, in one place a process being rapidly drawn in, along with its bundle of pseudopodia, only to give rise to another at another place. Unlike *Vampyrella Spirogyræ*, this form would appear to have no choice in selection of food.

Examples were found, sometimes side by side, of two different colours; in one the pearl-like granules were perfectly colourless and pellucid, in the other of a light greyish brown; in other respects the two organism were alike, and hence the authors were somewhat doubtful as to whether these were really distinct species or merely accidental varieties. Since they incline to the former view, as they never met any other tones of colour or intermediate tints, they describe them under distinct names. They were, further, long doubtful as to the propriety of a new generic name, as the form came so close to the description given by Cienkowski, for his Nuclearia.[1]

But the following circumstances decided them not to subordinate their form to Nuclearia. Though Cienkowski says (for his form) "rich in vacuoles" that would not at all characterise the completely "bubbly" parenchyme of Leptophrys, due to the constancy in the size of the vacuoles. Further, the specially characteristic equability in size and in the distribution of the granules, and the peculiar flow of the body into numerous lobes, find no mention in Cienkowski's description; it may be assumed, therefore, that these characteristics are wanting in Nuclearia. Again, the contractility of the vacuoles, and the peculiar mode of sucking in its nutriment in the latter, and the much larger size of the nuclei, are further striking points of difference.

In conclusion, the authors touch upon the question as to the possible identity of their *Leptophrys cinerea* with Cienkowski's *Vampyrella vorax*. But as the latter author does

[1] 'Archiv f. Mikrosk. Anat.,' Bd. i, p. 225.

not say anything of the peculiar richness in vacuoles, and further describes *V. vorax* as brick-red in colour, the possible identity seems to the authors to be excluded.

Although, then, there is a good deal of resemblance, the authors could not relegate their form to the genus Vampyrella for the two reasons—the peculiar bubbly nature of the protoplasm, absent in Vampyrella, and the presence of nuclei, not yet demonstrated in Vampyrella (hence, as well known, claimed as a Moneron).

Vampyrella Spirogyræ, Cienk.[1]

Cienkowski himself, in a subsequent paper,[2] touches on the proposed genus Leptophrys (referring to *L. cinerea*) and its relation to the above named. He again had an opportunity to investigate his *V. vorax*, and re-examined it with a view to decide if its colour were a constant feature as to discover if it could assume a vacuolar consistence.

In respect to the first inquiry, the author thinks it can be answered in the affirmative. Digestive cysts of *V. vorax* taken on the same occasion, amongst diatoms, showed red, brown, and white cysts, side by side; the young form emerging from these followed the same colours; those from the white cysts were colourless, the brown gave greyish-brown, and the red brick-coloured individuals. He is inclined to conclude that the colour depends on the nature of the food, though not proven; hence would refer the red and brown as well to *V. vorax*.

Touching the vacuoles, as he had previously been looking for contractile vacuoles only, he had given no attention to the ordinary vacuoles. He now states *V. vorax* possesses these in abundance, and hesitates not to refer *L. cinerea* (written *cinerasens* by Cienkowski), Hertwig and Lesser, to his own *Vampyrella vorax*.

Aranchula impatiens, Cienk.[3] (fig. 21).

With this name Cienkowski records a colourless, naked protoplasmic being, with the general characters of a Vampyrella, but distinguished by the presence of contractile vacuoles and by anastomosing, but little branched, pseudopodia. One of the most usual forms assumed by it is that of a long-drawn-out string, broadened out at the ends into radiating lobes; but such lobes may occur anywhere along

[1] "Beiträge zur Kenntniss der Monaden" in 'Archiv f. Mikr. Anat.,' Bd. i, pp. 203 et seq.

[2] Schultze's 'Archiv,' Bd. xii, p. 24.

[3] Cienkowski, loc. cit., p. 27, t. v, figs. 18—24.

the string. The body-mass consists of very fluid protoplasm, in which are scattered strongly refractive particles and a few contractile vacuoles. The author could discover no nucleus. Very characteristic are its energetic movements, as it sends out long strings in advance, which quickly draw after them the main mass, this play thereupon to be repeated in another direction. But this restless action is sometimes followed by a more quiet demeanour, the pseudopodia alone executing a tremulous and aimless waving about. A granular current is noticeable in the pseudopodia.

The author did not succeed in following out any development process. He only saw (like as in Vampyrella) the formation of pellucid, variously figured, digestive cysts, the contents colourless, fluid, the food-balls inclosed in vacuoles. These when commencing showed contractile vacuoles towards the periphery. The contents of these cysts did not become divided, but passed out unaltered through an opening in the wall of the cyst.

The author found this form in Germany and Russia, and in the brackish water of the Black Sea.

The only distinction between this form to distinguish it *generically* from Vampyrella seems to be the few contractile, not many seemingly non-contractile, vacuoles—a distinction of little importance. Even the "non-contractile" eventually disappear, and probably, after *long* intervals, reappear.

Gymnophrys cometa, Cienk.[1] (fig. 22).

This is described by the author as a moneron, whose anastomosing pseudopodia possess a distinct granular current, and is mainly characterised by the pseudopodia being confined to only a few points of the surface of the body, not regularly distributed over it. Gymnophrys is a naked, colourless, protoplasmic mass, without nucleus and without contractile vacuoles, from which are given off at any place, but always sparingly, very long branched and anastomosing, very wide-spreading pseudopodia. The movement of these ultimate thin pseudopodia, as also of the granules, is very quick, although the larger strings formed by them remain for hours unaltered. Ingesta seldom met with. The author observed no development process.

In respect to the position of the form, the author would regard it as a *naked* representation of the Amphistomatous Monothalamia.

But wanting a nucleus (as it would appear), it must, if it

[1] Cienkowski, loc. cit., p. 31, t. v, f. 25.

be truly an independent form, be *pro tem.* relegated to the Monera. I may, perhaps, be forgiven for the *guess*, but the figures of this Sarcodine remind one not a little of a *portion* of the mass of a Gromia become isolated and detached by some readily conceivable force, having wandered too far from the headquarters. If the author's suggestion be borne out, it would very likely form a parallel for the naked *Lieberkühnia* (Clap. et Lachm.), as compared with the Monathalamia Monostomata. It would be very desirable that Lieberkühnia could be rediscovered and subjected to a fresh research. Claparède's and Lachmann's supposition, that Bailey's Pamphagus could be one and the same thing is, I feel satisfied, quite out of the question; that form is a wholly different thing.

Plakopus ruber, E. Schulze[1] (fig. 23),

is the name given by the author to a curious Sarcodine, rendered unique, as it is, by the remarkable form of the pseudopodia. It is a naked acyttarian Amœban rhizopod, with pseudopodia, not in the form of lobes, or simple or branching, finger-like or filamentary prolongations, but taking the form of *thin, membrane-like lamellæ*, these not spreading, like ordinary pseudopodia, upon the substratum (as, for instance, on the glass slide), but projected free in the water, and uniting here and there where they touch, they form around the body-mass a number of irregularly rounded, cup-like, hollow spaces, widening upwards. The distinction into a hyaline, equally refractive ectosarc, whence are formed the pseudopodia and an inner body-mass, with its varied constituents, though without any sharp line of demarcation, can be readily made out. The most striking element in the interior are the scarlet, brick-red, or sometimes brownish-red, or it may be greenish, particles of varying size. These colours may be found gradually merging one into the other, some intensely green, others pale brownish-green, then reddish-brown, and finally a clear red. (I venture to think it might be as well denied that these coloured granules belonged to the form under consideration, as the green granules of Cochliopodium and others.)

A single or several nuclei are present, in the ordinary state not easily noticeable, but under reagents readily becoming evident. A comparatively large nucleolus is surrounded by a broad, clear, rounded border, its outer limits only seldom sharply marked.

[1] Ed. Schulze, loc. cit., p. 348, t. xix, figs. 9—16.

A variable number of different sized pulsating vacuoles is scattered through the body-mass.

When an example creeps flatly expanded on a substratum, the two regions of the body-mass—that is, the inner one with the above-mentioned elements, and the outer stratum of sarcode, quite hyaline or extremely minutely granulate, from which pass off the thin lamellar pseudopodia—appear sufficiently distinctly contrasted. But if, on the other hand, which is mostly the case, the elevated membranous pseudopodia form a complicated system of hollow cavities (as described), and this more at one side than the other, the limits of the two regions become more indistinct, and sometimes only with difficulty recognisable.

Ordinarily the inner mass sends up a number of slender prolongations with contained pigment-granules, more or less far between and through the septa of the superficial cup-like cavities, imparting to such an example, seen from above, a peculiar, irregularly radiate aspect. Sometimes a portion of the inner mass, destitute of colouring granules, but containing vacuoles, may even enter into a pseudopodial lamella.

Whilst mostly the free borders of the lamellar pseudopodia appear quite smooth, they sometimes appear toothed, as if bitten; *once* the author saw on the margin of one a few fine filamentary processes.

The author's efforts to "cultivate" this form were not successful, so that the only clue he was able to discover as to its reproduction was afforded by certain sharply bounded globular bodies, met with in the same material, of about the same diameter, surrounded by a thin, clear membrane, and containing a great quantity of similar coloured reddish-brown granules, as in Plakopus in the usual state, as well as a number of globular bodies (of about the same size as the nucleolus of this sarcodine), these sometimes distributed in an equatorial zone.

Mastigamœba aspera, Eilhard Schulze[1] (fig. 24),

is peculiarly remarkable for the possession, concurrently with indubitable pseudopodia, of a well-developed *flagellum*. The only hitherto recorded organism possessing both pseudopodia and flagellum appears to be that to which Carter (who saw but a single example) had given the name of *Amœba ciliata*;[2] it may be possibly (but appears scarcely) the same thing, but

[1] Loc. cit., Bd. xi, p. 583, t. xxxv, figs. 1—3.
[2] Carter: 'Ann. and Mag. of Nat. Hist.,' vol. xiii (1864), t. ii, f. 19.

must most likely be referred to the same genus, as well as the *Podostoma filigerum*, Clap. et Lachm.[1]

The present form resembling, as it does in several points, the Sarcodine described by Hertwig and Lesser as *Dactylosphærium vitreum*, might be mistaken therefor. But that form has no flagellum.

Notwithstanding the mobile character of the body-mass, and (like others of its class) constant changes of contour, still a certain type-form, that is to say, that general figure most frequently recurring and longest retained, was not to be overlooked.

This might be compared to that of a spindle, at one end more pointed, at the other broadly rounded off, and compressed above and below. From the surface of the body—so far as not in contact with the substratum—numerous finger-like pseudopodia proceed. These are about as long as the diameter of the body, usually simple, rarely joined at the base, and with rounded, sometimes conically, attenuated, never filamentary or pointed, extremities. Whilst the position and direction of the pseudopodopia, sometimes long drawn out and again wholly retracted, are, on the whole, variable, still a certain law of arrangement might be noticed, and when once noticed, it readily again strikes the observer. Thus, in the normal figure of the sarcodine, they are but very slightly developed on the "dorsal" surface, whilst, from the alteral margins as well as from the attenuated anterior extremity they somewhat copiously radiate; at the posterior end they remain comparatively short, thus the whole gains some of the superficial aspect of some laterally symmetrical creeping animal.

It is noteworthy that, by reason of the occurrence of the flagellum at a definite position of the body, this being directed straight forward, a differentiation of poles, with a definite principal axis—an anterior and posterior extremity—become expressed. But a definite transverse axis does not seem to exist, still less any real or permanent distinction between "dorsal" and "ventral" surfaces.

The body consists of a hyaline, strongly refractive, colourless cortical region, from which the pseudopodia are direct processes, and more thinly-fluid contents, permeated by reddish-yellow globules and colourless granules, the latter as usual, being the seat of digestion.

The most interesting characteristic of the form is the flagellum. This is about 0·06—0·08 mm. long, forming a

[1] Clap. et Lachm., 'Études sur les Infusoires et les Rhizopodes,' p. 441, t. xxi, f. 4—6.

very fine filament, of equable but hardly definable diameter, and considerable refractive power. It proceeds from the cortical layer without any basal expansion; it is not diminished at its apex, but ends as if abruptly cut off. In the ordinary progressing condition of the sarcodine, it appears precisely at the anterior extremity, and fully extended, though, as will be understood, that on certain alterations of form and figure of the body-mass ensuing, it is sometimes withdrawn from observation. When in full view it is carried like that of a Euglena, extended and tentatively waved about. It is sometimes spirally curved, the coils running along it like advancing waves. These movements may be arrested, the flagellum remaining in the same position for a considerable time, as if wearied. The author never saw any retraction of it, or division or branching, or any current of granules in it—or, in short, he did not observe any tendency to evince "pseudopodial" characteristics.

Another peculiarity of this curious form is its surface being covered over with minute bacillar bodies, best comparable, as it were, to certain bacteria, and of greater refringent power than the cortical substance itself. These little bodies ordinarily lie with their longitudinal axis parallel to the superficies of the body, on which they appear coherent; they sometimes stand off obliquely or vertically. Thus the whole surface gains that rough appearance which induced the author to employ his specific name. Sometimes, when a pseudopodium becomes considerably elongate, these bodies become separated, and the upper part of a pseudopodium may thus become almost or quite free from them and appear smooth and clear.

The author thinks it highly unlikely that this form could be identical with Hertwig and Lesser's *Dactylosphærium vitreum*, as the fringe of minute processes around that form are quite different from the bacillar bodies here described. Nay, Mastigamœba itself gives off sometimes very minute, thinly scattered, and slender but longer processes of similar nature (comparable to those of *Amœba villosa*), from the posterior pseudopodia.

The outer border formed by the ectosarc averages in breadth about 0·005 millimètre. Besides the minute, strongly refractive granules of varying size, characteristic of every sarcodine, other larger globules (some 0·003 millimètre in diameter and more) occur, partly colourless and then darkly and sharply contoured, partly yellowish-red or reddish-brown, imparting to the endosarc its orange-red aspect.

Near the limits between ecto- and endosarc, there occur in

the latter, one or two, rarely more, globular vacuoles, not showing distinct rhythmical pulsations, but still originating and again disappearing. These occur constantly at the posterior end.

Just under the frontal flagellum and from the anterior end of the granular endosarc an irregularly rounded, smoothly bounded, rather strongly refractive body, of about 0·009 millimètre in diameter, projects, rendered more striking as it does not appear in direct contact with the ectosarc, but is separated therefrom by a region of clearer, probably more thinly fluid, character. The outer contour of this clear space does not run parallel to the approximately round surface of the dark body, but is drawn out anteriorly into a point, which touches up quite to the base of the flagellum. Whether there were any direct communication of this clear space with the surrounding water—any kind of oral opening—the author could not decide. The dark body seems to lie in a depression of the endosarc, the thin fluid mass probably, indeed, encompassing it all round. In its interior it shows a number of minute, globular, sharply bounded, clear spots, which have the power to alter their positions, the whole body having the power to alter its figure from globular to oval, or bluntly angular.

It is doubtful whether the peculiar body so described is to be regarded as the whole nucleus or perhaps as nucleolus only. In the first case a nucleolus and nuclear membrane would be wanting; in the latter case the clear mass surrounding the dark body, sharply bounded, but not limited by a membrane, would be regarded as nuclear contents. Very striking, then, would be the connection of the anterior pointed end of the outer part of the nucleus with the body-surface of the whole animal and just at the place of the insertion of the flagellum.

The very few examples of this remarkable form seen by the author were rather mobile, and soon began, after some irregular turnings, to move straight away as described, with manifold alterations of form and position, the pseudopodia the while projected and retracted.

The author did not observe the act of inception of food, though he had several times seen the ejection of fecal matter and from the posterior end, without, however, perceiving any marked anal region; nor did he notice any kind of reproductive process.

LOXOSOMA.[1] By CARL VOGT, Professor at the University of Geneva. With Plate XXII.

THE paper opens with a historical preamble, in which the Author gives an account in chronological order of the various papers relating to the genus *Loxosoma,* which have appeared from the year 1863, when it was first observed by Keferstein, and almost simultaneously by Claparède, to the present time.

Vogt's researches were conducted at Roscoff, and the species which he has studied is one new to science, which he has named *L. phascolosomatum*, and briefly characterised as follows: "Tentacles 12—18. Pedal gland wanting; number of buds never exceeding two." It attaches itself to the pointed, caudal extremity of the worms (*Phascolosoma elongatum* and *margaritaceum*), where it forms a small tuft, hardly visible to the naked eye.

METHODS OF OBSERVATION.

As the *Loxosomas* are very firmly attached to the epidermis of the worm it is almost impossible to remove them unmutilated. To observe them *in sitú*, the extremity of the tail bearing the tuft of *Polyzoa* must be cut off with a pair of scissors, and placed entire under the compressor, care being being taken merely to fix and not to compress the polypides. In this way the movements of the *Loxosomas* and their mode of attachment may be readily studied. But to examine them with high powers it is of course necessary to detach them, and to do this, the Author recommends that the extremity of the tail of the annelid, after it has been cut off, should be scraped with a scalpel, and all the detritus thus obtained be covered with a piece of thin glass. Amongst mutilated *Loxosomas*, pieces of the stem, &c., many uninjured polypides, attached to fragments of the epidermis, are sure to be found. These fragments serve to prevent the undue compression of the animals by the glass, which merely fixes them sufficiently to render it possible to draw them with the *Camera lucida*.

The author has made his observations almost exclusively on living animals, by means of transmitted light. Patience and abundance of material have been the conditions that have secured his results. All his figures have been taken with the *camera* from living animals, and finished, as far as possible, with the object before him. They are in no degree diagrammatic; "for if I have a horror of anything," he says, "it is of the so-called semi-diagrammatic figures, in which authors mingle with the facts observed their own theoretic views, in such a

[1] "Sur le Loxosome des Phascolosomes" ('Loxosoma Phascolosomatum') par Carl Vogt, Prof. à l'Université de Genève. Translated and condensed, by the Rev. Thomas Hincks, F.R.S., from the 'Archives de Zoologie Expérimentale,' 1877.

manner that it is impossible to tell what has been observed and what has been imagined."

"I have worked," the Author adds, "upon sections hardened in alcohol or chromic acid; I have employed the different reagents in vogue, such as osmic acid, and I have not neglected the methods of staining so much practised now-a-days by histologists. But I must confess that all these methods of investigation have taught me nothing that I could not see in the living animal. If certain details were rendered more distinct, as, for example, the cells in the stem, which are coloured by the picro-carminate of ammonia, while the gelatinous substance filling it remains uncoloured, the tissues in general became so opaque under the treatment, that I no longer succeeded in reading their structure. I have, therefore, abandoned these methods, which demand much time and care, and in the present case could give me no positive information upon points which direct observation of the living organism had failed to solve."

The Body and the Skin.

The body of the *Loxosoma*, apart from the stem to which it is attached, may be divided into two parts: the *tentacular apparatus* and the *body proper*.

The former consists of a *hood* (A), and a variable number of tentacles attached to it, and is formed by a direct continuation of the skin surrounding the rest of the body (B), within which are lodged the digestive and reproductive systems. The space enclosed by the hood (*capuchon*) is called the *vestibule* (C), and into this the mouth, the generative organs, and the anus, open directly.

General cavity of the body there is none. There is no empty space amongst the organs; the gaps between the latter and the skin are occupied by hypodermic cells, out of which the generative organs are formed.

The form of the animal viewed in front may be compared to that of a pear reversed, the stem being attached to the enlarged extremity (Pl. XXII, figs. 2, 3, 4). But this pear-shaped body is flattened, or even concave on one side and convex on the other (Pl. XXII, figs. 1 and 5). On the concave side, and almost in the middle of the hollow, is a circular, dilatable opening, through which the tentacles are put forth.[1]

Throughout the paper the concave side with the opening is designated the *ventral aspect*, while the side which is convex and entire will be the *dorsal aspect*; the extremity to which the

[1] This peculiarity in the position of the tentacular crown, placed as it is on one of the sides of the body, instead of at its summit, has suggested the generic name.

stem is attached is designated the *posterior*, and the opposite the *anterior*. It must be understood, however, that these terms do not express any homological relation, but are simply topographic, employed to facilitate the comprehension of the figures and descriptions.

The skin of *Loxosoma* is composed throughout of two elements, a homogeneous and transparent cuticle and a hypodermic layer, made up of granulous cells, associated at certain points with muscular fibres, more or less pronounced.

The *cuticle* (*a*) is structureless; it is rather thick over the surface of the body proper and of the stem, but becomes attenuated over the tentacular region, though easily recognisable throughout. It is clearly elastic to a certain extent, and yields readily to the pressure of the internal organs, bulging out over the eggs and visibly throwing itself into folds under the influence of the muscular contractions.

The *hypodermic layer* (*b*), closely united to the cuticle, of which it is undoubtedly the matrix, is composed as a rule of a single stratum of very granulous cells, irregularly shaped, which projects on the inner side, and in which minute nuclei, differing but slightly from the granular protoplasm, may be detected with difficulty. This layer is coextensive with the cuticle, and preserves, for the most part, an uniform thickness.[1] It is continued over the tentacles and the stem; but in these two cases it combines with other elements, which will be noticed hereafter.

The author has no doubt that the rudiments of the generative organs and their contents are derived from the hypodermic cells. No histological element is met with, apart from these cells, that could contribute to their formation. The reproductive organs of *Loxosoma*, to employ the recognised phraseology, are therefore a product of the ectoderm.

The skin, speaking generally, over the whole extent of the body presents the appearance of an uniform, smooth layer, with a look of rigidity. At a definite point, however, between the posterior margin of the tentacular crown and the anterior extremity of the stomach there occur a few superficial folds or creases (*c*), which are palmate in form and placed transversely. They seem to depend on the position of the thick anterior lip-like appendage which guards the entrance to the œsophagus, as we shall see hereafter, making their appearance when it is closed and at rest, and disappearing when it is raised to allow of the entrance of food.

[1] One or two exceptions are noted, but they appear to have no special significance.—*Transl.*

Organs of Sense.

On each side of the body, placed somewhat on the dorsal aspect and on a level with the enlarged portion of the intestine (the *rectum*), is a papillary eminence (*d*, Pl. XXII, fig. 11), from which rise a number of short, somewhat rigid bristles. The cuticle is continued over the *papilla*, but is attenuated towards its summit. In the interior a number of elongated, conical, converging cells are visible, with the pointed extremity directed upwards, and apparently in direct communication with the bristles, which rise from the *papilla*. These bristles are acuminate, and appear to be slightly flexible, but exhibit no movements of their own.

The *papillæ*, on the contrary, are eminently contractile; they shrink into themselves; the summit is drawn inwards, leaving a crater-like depression, in which the bristles are concealed, and when the contraction reaches its extreme point nothing is visible but an insignificant rising of the skin without any trace of special structure. The *papillæ* are present on the buds in the later stages of their development, before their separation from the parent, and on the two sexes alike. The contained cells, like those which compose the hypodermic layer, are finely granulated and without any apparent nucleus.

As to the significance of these bodies, they resemble in structure the tactile or sensitive *papillæ*, which occur in so many animals, and have, no doubt, a similar function.[1] A difficulty indeed lies in the way of this interpretation, from the fact that no observer has yet detected any trace of a nervous system. The author has sometimes fancied that he could make out lines, as it were, radiating from the *papillæ* towards the middle of the body, but there was so little definiteness about them that it was impossible to draw them, and they might, with equal probability, be taken as indications of superficial wrinklings in the cuticle. However this may be, the existence of these structures, so evidently tactile in their nature, seems to lead almost of necessity to the conclusion that a nervous system must exist, perhaps similar to that discovered by Nitsche in *Pedicellina*, and of which that author considers he has found some indistinct traces in *Loxosoma*.

[1] The *papillæ* of *Loxosoma* bear a close general resemblance to the tactile organs which occur on the tentacles of the *Hydroida*, and which were first described by Dr. Strethill Wright as *palpocils*. I am not aware that any similar structure has hitherto been noticed amongst the Polyzoa, with the exception of the tuft of *setæ* or sensitive hairs that is met with between the jaws of the avicularium in some of the Cheilostomatous forms; unless, indeed, the extremely delicate setiform processes ranged along the *back* of the tentacles in some species must be placed in the same category.—*Transl.*

The Stem.

In the present species this organ is of very simple structure. It is invested by a cuticle of tolerable thickness, especially in old individuals, in which the lower portion of the stem takes on a yellow colour, whilst it at the same time becomes more rigid (Pl. XXII, fig. 1). Beneath the cuticle are the hypodermic cells, presenting the same characters as over the whole of the body, but widely separated, ranged in line and in communication with pale muscular fibres, which traverse longitudinally the entire length of the stem, and are distributed over the base of the body. These fibres, which are very delicate and slightly connected, are clearly placed immediately within the cuticle.

The cells are attached to their inner surface, and are arranged, like beads, along the fibres, which have all the appearance of being excreted from their walls.

The centre of the stem is occupied by a solid gelatinous substance, transparent as crystal, in which are disposed minute nucleated cells of a pale colour, fusiform or triangular, and from these proceed in all directions most delicate fibrils, which ramify and anastomose, so as to form a complicated network, the ramifications sometimes spreading in one plane, sometimes plunging towards the interior of the stem. This structure is identical with certain connective tissues that are met with in all parts of the animal kingdom.

A pedal gland, such as has been described by Kowalewsky and Schmidt in other species, is altogether wanting. The lower extremity of the stem is pointed like the nib of a pen, and though it adheres firmly to the epidermis, there is no sign of any special organ of attachment.

Transverse muscular fibres, antagonistic to the longitudinal fibres, have not been observed. The muscular action must therefore find its antagonistic force in the elasticity of the cuticle and of the connective tissue filling the stem. The movements of the latter are very energetic, and, besides bending to one side and then straightening itself, which is frequently done, it is occasionally contracted into a spiral.

The Tentacular Apparatus.

This important portion of the structure is made up of two parts—the *hood* (A) and the crown of tentacles (D).

The former is an attenuated extension of the skin, and has exactly the shape of the hood of a cloak, which is fastened in front of the person by means of a string. The body-wall, strengthened by a thicker and more rigid cuticle and a more higher developed hypodermic layer upon the dorsal side, rises

towards the anterior extremity of the body, and the hood is thus turned downwards towards the ventral aspect, of which it occupies the upper half. When it is fully extended, if the polypide is viewed in profile, a membranous expansion is visible, distinctly separated from the wall of the body by a circular depression, having the form of a crown, slightly raised and delicately crenated round its outer edge. When, on the contrary, the hood is contracted, it completely conceals the tentacles folded in towards the interior, and its orifice is reduced to a circular spot, which it is often difficult to detect. The cavity, enclosed in front by the hood and below by the internal organs, is the *vestibule* (C, Pl. XXII, fig. 1).

The hood is eminently contractile, its contractibility being due to a large circular *sphincter* (*e*), composed of delicate, parallel muscular fibres, which form a band round its orifice.

Radiating muscular fibres to act as antagonists the Author has failed to find, nor has he observed any histological element whatever to which this function could be assigned. He, therefore, concludes that it is discharged by the elastic cuticle of the hood, aided by the elevation of the tentacles which press against its internal surface.

The *tentacular corona* (D) is composed of the tentacles or arms.

It is an important observation that the number of the tentacles increases, not only on the bud while in course of development, but also on the polypide after separation from the parent, and when the reproductive elements have made their appearance. The number at the time of detachment is twelve; but fourteen, sixteen, and eighteen have been met with; the latter seems to be the limit. This observation shows that the number of tentacles cannot be relied upon in the case of *Loxosoma* as a specific character.[1]

The tentacles are always bent, even when most fully expanded. They are not retractile, but can be partially coiled up within the vestibule, and in this condition they exhibit slow, vermicular movements. They are attached to the hood by a certain portion of their external surface, but the inner extremity is free and rounded off, and projects into the vestibule.

The structure of the tentacles is not easily determined. When viewed in profile (Pl. XXII, fig. 10) a pretty thick cuticle is seen to form their outer surface, and beneath this the hypo-

[1] Amongst the *Polyzoa* generally there is great variability in the number of the tentacles within the limits of a species. The sub-order *Ctenostomata*, however, offers an exception; in this division the character is so constant that it has been employed as a generic distinction. It is difficult to understand what special significance there can be in the presence of a few more or less of these (usually) variable appendages.—*Transl.*

dermic layer extends throughout the entire length of the arm. From this layer the large, pale, slightly granular cells (*g*) which support the whip-like vibratile cilia, are readily distinguishable; they are ranged in two rows. There are indications which seem to show that the cuticle is continued over the *inner* surface of the tentacle. Besides the large whip-like organs, there are delicate vibratile cilia distributed over the internal surface of the hood between the tentacles.

The movements of the *cilia* are controlled by the will of the animal; when the tentacles are folded in, they may be seen to execute very slight, undulatory movements, whilst they play with perfect regularity when the tentacles are expanded. The movements of the latter seem to the author to depend on those of the hood. No contractile tissue has been noticed in the tentacles, nor any muscular fibres. The author has been unable to verify Kowalewsky's observation of longitudinal fibres at the base of the arms (in *Loxosoma Neapolitanum*). Nor has he detected any cavity or internal canal, the whole space within being filled by the cells. Schmidt regards the tentacles as tubular, and believes that they are elevated by the injection of fluid into the cavity. Any such mechanical arrangement the Author considers to be simply impossible under the circumstances. Even if the structure of the tentacle itself were such as to admit of it, it would be necessary that this cavity should be in communication with a space, capable of being contracted or compressed, when the arms were to be raised, and again expanded when they were to be lowered. In fact, however, the tentacles are only in connection with the vestibule, which is always more or less open, and most widely open when the arms are raised. It appears, therefore, that they must be elevated by the relaxation of the sphincter; that being attached to the hood by their external surface, they are drawn outwards when it opens, whilst they are bent inwards as it contracts. The vermicular movements, to which allusion has been made, seem to depend on contractions of the cells themselves, especially of the hypodermic cells, which are strongly developed on the tentacles.

The Digestive Canal.

This portion of the structure is most readily examined in young individuals, in which the parts are not concealed by the growth of the generative organs. The author was much assisted in his investigations by feeding the polypides with carmine, an antiquated, but very serviceable practice. The *mouth* (*i*, Pl. XXII, fig. 5) is placed on the median line, at the base of the tentacular corona, on the ventral side. It is in the form of a very wide funnel, with thick and solid walls. Viewed in profile, this funnel-shaped

opening is seen to be furnished with two lips, one ventral (*k*) and button shaped, the other dorsal (*l*), recurved like a hook, and projecting freely into the vestibule.[1] The inner surface of these lips is covered with fine, short *cilia*, which extend into the narrow, curved canal of the *œsophagus* (*m*). The latter passes down the ventral side of the body, and is also enclosed by thick walls. From the œsophagus the vibratile epithelium extends over the whole internal surface of the intestine, and is always so arranged that the alimentary matter is made to revolve rapidly in the various cavities.

At the base of the body, close to the stem, the œsophagus bends sharply upwards, and opens into a round, thick body—the stomach (*n*). When it is viewed in front, a nipple-shaped prominence is visible, placed posteriorly towards the sides in the middle, which is the opening into the œsophagus—the cardiac valve—and near this there is almost always a very vigorous play of *cilia*. The true cavity of the stomach is above, surrounded by very thick walls, with radiating striæ, and lined internally with granular cells, of a yellow colour, which always contain small drops of oil, and are arranged in radiate fashion (Pl. XXII, fig. 3).

The author adopts the common view that these cells have a biliary function; but he also regards them as absorbents. In polypides that have been fed with carmine, they assume an orange or scarlet tint, clearly showing that there has been an absorption of colouring matter, which has modified the ordinary amber-yellow of the cells. This orange tint continues long after all the carmine that had been swallowed is evacuated, and has a diffused appearance, as if a fluid might have pervaded the cell. In no other portion of the intestine is the slightest trace of coloration apparent.

The pyloric orifice, opening from the digestive cavity into the intestine, is placed on the dorsal wall of the stomach, at a rather higher level than that of the œsophagus. The *intestine proper* (G) lies close upon the dorsal wall of the body, and is divided into two pyriform compartments, connected by a short and narrow tubular passage. The first of these compartments represents the *middle intestine*, and the second, the rectum (H).

The rectum is generally so completely closed at its upper extremity as to show no trace of an opening. From time to time, however, a narrow orifice makes its appearance in the thick wall at the summit, exactly opposite the centre of the tentacular crown, through which the fæcal matter is discharged into the vestibule. After its expulsion the opening entirely disappears.

[1] Judging from Nitsche's figures, there seems to be no trace of these lip-like appendages in *Pedicellina*; but the dorsal one, which is the larger and more conspicuous, has its representative in *Rhabdopleura*, according to Sars.—*Transl.*

From watching the movements of the fæcal matter (carmine) within the vestibule, the author has assured himself that there is no partition or floor between the hood and the vestibule, and that there is, therefore, no ground whatever for identifying the latter with a general cavity of the body.

The Reproductive Organs.

The author has no doubt that the species which he has investigated is diœcious; Schmidt and Nitsche, on the contrary, regard the *Loxosomas* as hermaphrodite.[1] The generative organs in their earliest condition occupy the same position in both sexes; but the course of their development is different in each.

The male.—Viewed on the ventral side, the male polypides exhibit, in the median line of the body and between the tentacular *corona* above and the stomach below, a thick-walled vesicle, almost circular in shape, which is usually filled with a number of filiform zoosperms massed together. When the *dorsal aspect* is in view, careful manipulation shows that the intestine lies above it, as the œsophagus and the palmiform folds do, when the *ventral surface* is uppermost. This central seminal vesicle is connected on both sides by two very short canals, or rather perforations in its thick wall (Pl. XXII, fig. 3), with two large organs (*t*) placed in pyramidal spaces lying between the tentacular crown, the lateral extensions of the stomach and the skin. These organs vary in appearance in different individuals (Pl. XXII, figs. 2, 3, 4). In some cases, almost invisible from their transparency, they have in others a distinctly cellular appearance, and almost look like ovaries filled with minute nucleated ova. It is soon apparent, however, that the contained cells bear no real resemblance to ova, and further, that in the interior of the organs there is frequently a hollow space, and that numerous zoosperms are moving about in this cavity (Pl. XXII, fig. 3), which communicates by the canal just mentioned with the seminal vesicle. The Author has seen the zoosperms passing through the canal into the vesicle, and has no doubt that they originate in the cells composing the organs referred to, which must, therefore, be regarded as *testicles*.

According to Schmidt, the zoosperms make their way through two trumpet-shaped tubes, lined with cilia, from the vesicle into the *ovary*. The Author, on the contrary, has seen the mass of intertwining zoosperms (*n*), filling the vesicle, suddenly expelled by a violent contraction of the whole animal (Pl. XXII, fig. 4). Driven into the vestibule, it revolved rapidly on its axis for awhile, and was ultimately launched into the water, where it disappeared. The vesicle afterwards collapsed, and was hardly distinguishable.

[1] In the species investigated by Kowalewsky, the sexes are represented as distinct.—*Transl.*

This observation shows that the zoosperms are destined to fertilise the ova in other individuals, and not in the polypide in which they originate. This fact, however, is not conclusive against hermaphroditism, and the separation of the sexes must be established by the study of the female.

THE FEMALE.—In young individuals and in buds still attached, some granular cells, hardly distinguishable from those of the hypoderm (*v*, Pl. XXII, fig. 2), are visible in the space occupied at a later period by the testicles or the eggs. In the males two of these cells, placed one on each side, increase greatly in size and are developed into the testicles. In the female there are many on each side containing oil-globules of a yellow colour, and in some respects not unlike the hepatic cells. Nuclei were not observed in them, but might readily escape detection; nor was it possible to decide positively whether or not they were enclosed in a very delicate sac. Certain it is, however, that the *ova* (*w*), relatively of large size, are soon distinguishable, occupying the same position as the testicles. At first a single egg only is visible on each side, placed close to the wall of the stomach, round or slightly oval, enclosed in a delicate vitellary membrane and an exceedingly transparent ovisac, and showing in the centre of its granular vitellus a large transparent germinal vesicle with a circular nucleolus. The egg increases rapidly in size, and the vitellus, nearly transparent at first, becomes more and more opaque from the multiplication of the granules. Viewed by reflected light, the *ovum* appears of a chalk-white colour. Behind the first egg a second is soon developed, whilst the former, as it increases, is separated from the latter, and moves towards the dorsal side within the vestibule.

The eggs multiply without intermission, the older being pushed forward in the vestibule, where they accumulate in increasing numbers until it is entirely filled by them. At this stage it is evident that they are enclosed in a very thin-walled ovary, which takes the form of clustered ovisacs.

The vestibule, then, and especially the dorsal portion of it, is in the female a true brood-chamber, in which the ova enclosed in their ovisacs pass through the various stages of development, finally leaving it, on the rupture of the sacs, as ciliated larvæ.

It is a curious fact that the ova are developed alternately on each side of the body—first an egg on one side, then on the other, and so on to the end.

The Author has never seen, amongst the hundreds of polypides examined, any trace of testicles or seminal vesicle in individuals carrying ova, nor has he ever found an ovum in those which were furnished with the male organs. The *Loxosoma phascolosomatum* is, therefore, diœcious; and in this respect, if Schmidt's observa-

tions are correct, differs widely from the species described by that author.

Sexual individuals, both male and female, are found on the same *Phascolosoma*, but the tufts (or colonies) are to a great extent either male *or* female. The female tufts may be recognised at once under the lens by the masses of white ova, whilst the male are composed of a multitude of transparent individuals, with only here and there a white point. The *colonies* are, therefore, in great part, but not absolutely, unisexual. Whilst a large proportion of the polypides in a tuft are of one sex, there are always a few individuals amongst them of the opposite sex. The clustered ovisacs, situated at first on each side of the intestine, but which are pushed little by little into the vestibule, are analogous to the incubation-pouch (*die Bruttasche*) of the *Pedicellinæ*, described by Nitsche, with this difference, that the latter exists from the first and possesses very thick walls, whereas the ovisacs of *Loxosoma* are always very thin, and are developed gradually as the eggs increase in size.

The Ova and Larvæ.

The Author proceeds to trace the development of the ovum through its various stages. After the commencement of segmentation the granulations become more and more opaque, the eggs, viewed by direct light, present a chalky appearance, and nothing but the outlines of the vitelline mulberry masses are distinguishable. The Author was able to make out the commencement of the segmentation, marked by the appearance of two transparent nuclei in the (as yet) undivided vitellus; but the subsequent stages he was unable to follow, though the progress of the segmentation was indicated by the increasing number of nuclei, which were visible in the ovum when submitted to compression. By the same means he was able to determine that the cells situated at the centre had become more opaque than those at the circumference—a proof that the differentiation into ectoderm and endoderm had taken place. The opacity of the ova, which yielded to no reagents, prevented him from tracing in detail the formation of the *gastrula*.

M. Barrois seems to have succeeded better.[1] He states that development proceeds with perfect regularity up to the 8-segmentation stage, after which one half of the egg begins to divide more rapidly than the other, and in this way a *gastrula* is formed, by a process closely resembling epibole. The Author, from certain observations, was led to infer that in the present species the formation of the *gastrula* commences at a later

[1] "On Larval Forms of Bryozoa," 'Comptes Rendus,' Sept. 6th, 1875, p. 443; 'Annals N. H.,' ser 4, vol. xvi, p. 301.

period. The structure of the latter may be traced in such an ovum as the one marked 9 in Figure 6. It takes on a very broad form, the circumference has become transparent, whilst in the centre an opaque mass is visible, which is in connection with the periphery at a single point. At a later stage a funnel-shaped depression, clothed with very delicate cilia, makes its appearance at this point and constitutes the mouth.

The Author has fully satisfied himself that the central, opaque, flask-shaped mass (Pl. XXII, fig. 6) presenting a mammillated appearance, owing to the large seed-like cells of which it is composed, has at first only a single point of communication with the periphery. Its posterior extremity, which is broad and rounded, is always bordered by a clearly defined outline at some distance from the periphery. This opaque mass is, as it were, the first rough draught of the digestive canal; it follows that in the *gastrula* the digestive canal is a cul-de-sac and destitute of an anal orifice.

The Author next describes in detail the perfect larva (Pl. XXII, fig. 7), remarking upon the difficulty of giving an accurate sketch of a creature which is so rapid and erratic in its movements, and changes its shape so continually.[1]

In its usual condition, when expanded, it resembles a very wide bell, the thickened border of which is formed by a wreath of long cilia, with a clapper-like body projecting in the centre. Near the enlarged and rounded summit of the bell are two red eye-specks situated near the edge of two circular depressions, surrounded by an elevated border from which a few setiform cilia rise. The eminently retractile clapper bears a central mouth, surrounded by four eminences, and at the opposite extremity of the bell is a button-shaped caudal projection, also retractile and furnished with a few stiff cilia.

Passing to the details of the structure, the clapper, which may be called the *buccal mammilla* (*O*), can be withdrawn entirely so as to leave a kind of funnel, but usually has the form of a truncated cone, the extremity of which is furnished with very long cilia, while the margin of the buccal cavity and the cavity itself are clothed with extremely delicate and short cilia. The margin is divided into four rounded lips. The *mammilla*, like the rest of the body, is composed of two dermic layers, a transparent

[1] I have experienced the same difficulty when attempting to master the external characters of the kindred *Pedicellina* embryo. Its restless activity, its rapid and irregular motion, and the frequent changes of form in its eminently contractile body, made it no easy matter to gain any clear idea of its actual appearance. It was necessary to make the most of the occasions on which it anchored itself for a few seconds by means of the ciliated base of the body. It is hardly wonderful, under the circumstances of the case, that there should be differences between the reports of competent observers. —*Transl.*

cuticle and a layer of hypodermic cells. To these must be added, in the interior, the tissue of the intestine itself (the endoderm) of an obscurely cellular structure.

The alimentary canal (N) has the form of a long-necked flask, but is liable to variation according to the degree in which it is contracted. It terminates below in a large, rounded *cul de-sac*, which is often much dilated. When in this condition, the author has noticed two dark parallel lines, enclosing a lighter longitudinal space, which originates at the base of the *cul-de-sac*, and ascends with a slight curve towards the buccal aperture. This is, no doubt, the rudimentary state of the intestine proper, and a small *papilla* at its upper extremity marks the future position of the anal orifice, so that the plan of the alimentary system is already in the larva conformed to the type of the adult animal. At the same time it is undoubted that the *cul-de-sac* (stomach) is completely closed below, and is absolutely separated from the hypodermic layer.

The ciliary crown or wreath (M).—This is a large circular organ which can be expanded or drawn over the buccal prominence like a hood. It is sometimes inflated, and sometimes contracted so as to resemble in form the *vela* of the Gasteropod embryo, a resemblance that is increased when the buccal *mammilla* is wholly withdrawn, leaving a depression lined with cilia, which appears to divide the crown into two lateral expansions. The cilia on the wreath are long and stout, and are connected with large granular cells which are clearly developed from the hypodermic layer.[1]

The eye-specks (S) make their appearance at an early stage of the development, while the embryo is still enclosed in the ovum. They are of a yellowish-red colour, situated inside the hypodermic layer, and seem to be nothing more than pigment masses. Neither nerves nor refractive corpuscles could be detected.[2]

The spectacle organ (R) is composed of two circular hollows surrounded by a thick border made up of cuticle and hypodermic cells, which forms a kind of bridge between the hollows. At the bottom of each depression are five or six conical *papillæ* supporting long and broad cilia, which can be pushed forth or withdrawn to the bottom of the hollow.

The *caudal appendage* (T) is situated in the centre of the

[1] The embryo of *Pedicellina* closely resembles that of *Loxosoma* in this portion of its structure. It is furnished with a kind of contractile mantle, which can be folded over the anterior surface of its body or turned outwards, so as to form a ciliated locomotive organ.—*Transl.*

[2] In the embryo of the Cheilostomatous genus *Bugula*, Nitsche has described eye-specks furnished with a refractile corpuscle. In some cases as many as ten were present on a single individual.—*Transl.*

posterior extremity of the body, and consists of a highly retractile nipple-shaped body, bearing a few stiff setæ on its summit. It can be withdrawn, so as to become almost invisible.

As to the developmental phases which connect the gastrula with this curious larva, they are perfectly simple, and it may be said that the rough draft, both of the form and of the different parts of the larva exists already in the *gastrula*, and that it is merely by successive differentiation of the rudimental elements that the perfect embryo is constituted.

The author has been unable to trace the later stages in the history of the embryo, or to determine the precise mode in which it is transformed into the perfect animal. He has observed occasionally on the skin of the *Phascolosomas* club-shaped bodies, composed of a thin cuticular envelope, filled with very transparent protoplasm containing refractive granules, which were attached by the smaller extremity and completely closed above. He is inclined to believe, though quite unable to speak with any certainty on the point, that these bodies may enter into the series of transformations; that the embryo, after becoming attached, may be enclosed by a thick cuticle, and undergo a complete dissolution of the tissues, such as has been observed in other Bryozoan larvæ, and that finally within the elongated cyst formed by the cuticular envelope a polypide may be developed by budding. After careful and prolonged examination, however, no distinct traces of any such process have been determined.

On the other hand, the analogy supplied by the study of the larva of *Pedicellina* affords no support whatever to this view.[1] In the latter the internal organs are most fully developed as they exist in the adult; even the rudiments of the reproductive organs and of the brood-chamber are distinguishable. It is difficult to imagine that all these organs thus definitely constituted are to disappear that a new and similar set may be evolved, and it is therefore probable that the larva of *Pedicellina* undergoes no dissolution of its tissues, but passes into the perfect animal through the loss of the ciliary organs and the development of a tentacular *corona* and a stem. Is it likely, then, that such being the course of development in *Pedicellina*, the kindred *Loxosoma* passes through a totally different cycle of ontogenetic phases?

In the absence of conclusive facts the Author leaves the question for future decision.[2]

[1] It would surely have been nearer the mark to say that the case of *Pedicellina* affords a very strong presumption against any such supposition.—*Transl.*

[2] The author has somewhat underrated the amount of our knowledge respecting the larval history of *Pedicellina*. So long ago as 1845, Van Beneden, in his 'Recherches sur les Bryozoaires,' described the larva of his *P. Belgica*, and gave a very interesting account of some of the later

Reproduction by Budding.

Buds are produced on both sexes, and always in the same position, at the sides of the ventral surface. They are developed without any reference to the sexual reproduction, being found on females laden with ova, and on males in which the seminal vesicle is in full activity. It seems probable that the buds are of the same sex as the individuals that bear them. There are never more than two buds, and they are always unequally developed. Frequently there is only one, and in the month of July, and at other seasons the great majority of the *Loxosomas* exhibited no trace whatever of gemmation. The Author thinks that the comparative scarcity of buds, in which this form differs from all others, except the *L. singulare*, Keferstein, may be employed as a specific distinction.

The production of buds is the work of the hypodermic layer alone. No other portion of the body is concerned with it; the entire structure is developed from the ectoderm of the parent.

The first indication of the bud is an elevation of the hypodermic layer, over which the cuticle arches. It is in some degree separated from the rest of the envelope and from the other hypodermic cells by a more or less marked cuticular fold.

The arched cavity formed by this rising is soon filled by the

stages of its development. He observed the growth of the tentacles on the anterior (or inner) surface of the ciliated mantle or velum, and the subsequent disappearance of the cilia. He also noticed the formation of a kind of pedicle at the base of the body—a prolongation of the caudal appendage; by which the larva attached itself, and actually witnessed the attachment. At this time, he states, the digestive canal was completely formed. These observations are conclusive, and show that it is not merely "probable," but certain, that the dissolution of the tissues is not one of the developmental changes through which the *Pedicellina* larva passes. I have myself met with the larva of *P. echinata* attached, retaining much the same form as when free, exhibiting just the differences of aspect that one might expect during the transition into the adult state, but no sign of any further transformation (*vide* 'Micr. Journ.,' v. xiii, n. s., p. 33). Seeing it in this condition, and knowing that its internal structure is already conformed even in detail to the type of the adult, it would seem almost impossible to doubt that the further course of development must be straight onwards towards the perfect form; Van Beneden's observations show that it is so.

When we consider the close affinity between *Pedicellina* and *Loxosoma*, and the general agreement of their embryonic states, it is certainly in the highest degree probable that the cycle of development is the same in both. It appears from the observations of Vogt, that in the latter genus the whole conformation of the embryo is more delicate, and the internal organs are less strongly defined than in the former; but at the same time the structural plan is sketched in its completeness, and it is equally difficult in both cases to believe that it is afterwards obliterated merely to be renewed by a different process. It may, I think, be considered all but certain that the larvæ of the *Entoprocta* pass directly into the perfect animal.—*Transl.*

deposition of minute masses, to which the name *cell* cannot be applied, as they are mere collections of protoplasm, unprovided with any distinct walls, having a waxy appearance and destitute of granules or nuclei. These masses, which must be regarded as accumulations of a homogeneous protoplasm, do not completely fill the cavity; there remains in the centre a small empty space, which, viewed from above, appears round, but when seen in profile has the form of an elongated hollow. As the bud enlarges this hollow becomes more distinctly defined in the centre of its anterior region, surrounded by the waxy, transparent substance, which takes the form of a heraldic escutcheon. This internal cavity has no connection with the periphery; it is only at a later stage, after the tentacles have appeared, that it opens out on the circumference to form the central aperture of the tentacular hood. As development proceeds it becomes evident that the primitive tissure in the bud represents the cavity of the hood. Below it three successive accumulations make their appearance, the first large, transverse, similar in appearance to the hood, which is soon hollowed out in the centre, and represents the *stomach;* behind this is placed a round, opaque, granulated mass, which may be called the *pedal body;* and at the bottom of the bud, near the point of attachment, there is a third, divided into two parts, and with transverse bands alternately granular and transparent—*the pedal gland.* The spaces between these various organs and the hypoderm are filled with minute granular cells, two of which, situated between the tentacular escutcheon and the stomach, are larger than the rest, and form the rudiments of the *reproductive organs.* (Pl. XXII, fig. 12, n., x, Y, and v.)

The Author differs from Nitsche as to the primitive contents of the bud. The latter considers them to be cellular, the product of a central cell, through continuous division and subdivision. The former believes that the various organs are formed by the differentiation of an undivided sarcodic mass.

Pursuing the development of the various organs, as soon as the stomach-mass is distinctly defined a triangular figure becomes apparent on the dorsal side of the tentacular escutcheon, extending from the stomach towards the primitive hollow; it contracts in the middle, enlarging above and below, so as to form two apparently closed cavities, the *intestine* and the *rectum.* The walls composing them are of great thickness; internal cavities are not perceptible from the first appearance of the outlined form. The Author infers that this structure is not formed by the coalescence of cells, but rather by a differentiation of the sarcodic mass that surrounds the primitive cavity. The anal orifice makes its appearance at the last stage, along with the opening of the hood.

A little later an indistinct outline of the funnel of the œsophagus is traceable on the ventral side of the escutcheon and towards the lower part of it.

The *stomach* is at first a perfectly solid mass, but is soon hollowed out and brought into communication with the cavities of the œsophagus and intestine (Pl. XXII, fig. 12, n). The ciliary movement is only visible when the bud is about to detach itself, and the hepatic cells are developed at a still later period.

The *reproductive organs* are distinguishable as such towards the latter half of the life of the bud. Shortly before its detachment they appear as two round, granular masses, united by a very short canal, and placed on each side, between the hood and the lateral expansions of the stomach. At this stage, however, there is no trace of the seminal vesicle. Soon after the separation of the bud from the parent these organs assume their definite form.

Of all the principal organs the *tentacles* make their appearance latest; they are distinguishable at first as minute warts on the border of the primitive hollow.[1]

The *tactile organs* are present in all the mature buds, but the Author was unable to determine the stages of their development.

As to the *stem*, there are important differences between the Author and other observers (Claparède and Nitsche). The latter hold that the bud (in *Loxosoma Kefersteini*) puts forth its stem on the side opposite to the point by which it is attached; the former has no doubt that, in the present species at least, the bud, after its separation, fixes itself by the very same extremity by which it was attached to the parent.

Two distinct formations are visible in the stem of the bud. In the immediate neighbourhood of the stomach there is a mass of opaque and granular cells, forming an elliptical body placed

[1] In the ordinary process of gemmation amongst the other *Polyzoa*, the tentacles are almost the *first* organs to make their appearance. A small and simple sac, on which at a very early period the rudimentary tentacular crown is visible, is the primary stage in the development of the bud. The digestive canal is formed subsequently out of the primitive sac attached to the tentacles. Of course, in this plan of development, the anal orifice is of necessity thrown without the tentacular ring, which before the formation of the intestines closely embraces the oral aperture. On the other hand, in the plan of development which obtains amongst the *Entoprocta*, an ample vestibule is first defined (= the space surrounded by the mantle in the embryo), *not in connection with the oral aperture merely, but occupying the whole of the upper portion of the bud and immediately closed in by the body-wall*; beneath this the digestive canal is formed, and into it both its orifices naturally open. The tentacles are ultimately developed within the border of the capacious hood, which walls in this vestibule, and therefore surround the anal as well as the oral aperture. The anomalous position of the anus, therefore, in the *Entoprocta*, is connected with very radical differences in the plan of development, and is a character of great significance.—*Transl.*

transversely, which may be called the *pedal body*. It projects on the ventral surface of the bud, and, seen in profile, seems to be divided into two halves, separated by a transparent space, and has much the appearance of a gland. The projection has the form of a large nipple, and is situated, as has been mentioned, on the ventral surface. Now, if the present species resembled *L. Keferateini*, this projection would be the point by which the bud would be attached to the parent; but this is not the case; the bud is actually attached by the extremity of its axis, and in this terminal portion of it occurs the analogue of the pedal gland, which in some species is permanent, but in *L. Kefersteini*, as well as in the present form, disappears entirely after its detachment.

This *pedal gland* is very distinctly visible in the buds, and at an early stage; but in the youngest polypides examined, all trace of it, as well as of the pedal body, had disappeared; the stem had become longer and more slender, and was provided with its connective tissue and muscular fibres. The Author concludes, from the observations he has made, though imperfect, that the connective tissue is formed at the expense of the pedal body, and that the bud attaches itself by the extremity by which it was in communication with the parent. The pedal gland seems to be absorbed after furnishing the secretion by which the animal is permanently fixed.

GENERAL REMARKS.

The author proceeds to consider the systematic position of *Loxosòma*. Schmidt would separate it from the Polyzoa, but finds no very decisive indications of its true position. All the other writers who have studied it—Claparède, Keferstein, Kowalewsky, Leuckart—are agreed in placing it amongst the Polyzoa. Nitsche, whilst admitting that its systematic place is open to discussion, unites it with *Pedicellina*, and includes the two genera in a distinct family of *Polyzoa*, the *Entoprocta*, characterised by the position of the anus *within* the tentacular ring. The latter author lays down the following propositions:

1. An individual *Loxosoma* exhibits exactly the same conformation as an individual *Pedicellina* in all essential points.

2. The genus *Loxosoma* differs from the genus *Pedicellina* in the following secondary characters:

a. The *Loxosomas* are isolated individuals, whilst the *Pedicellinæ* form colonies.

b. The stem of *Loxosoma* is less distinctly separated from the body than that of *Pedicellina*,[1] in which a diaphragm divides the two regions.

[1] There are differences in this respect amongst the *Loxosomas*. In a species procured off the coast of Spain by the Porcupine Expedition, for

c. In harmony with their solitary condition, the *Loxosomas* are often furnished with a pedal gland, which is universally present in the young state; whilst the *Pedicellinæ*, rooted by means of a stolon, are destitute of it.

d. *Loxosoma* only produces a small number of ova, and has no true brood-chamber like *Pedicellina*.

Our Author accepts these propositions with some slight qualification. He has never seen *Pedicellina* more crowded with ova than *Loxosoma*, in which he has counted as many as thirty in all stages of development, while as to the brood-chamber, it has its analogue in the clustered ovisacs, which have been previously described. Besides the distinctions noted by Nitsche, an important difference between *Pedicellina* and *Loxosoma* is to be found in the position of the tentacular crown and the general conformation of the body. The former is placed on the *ventral side* in *Loxosoma*, while it occupies the extremity of the axis of stem and body in the *Pedicellinæ*. The body of the latter is laterally compressed, that of the former vertically. The tentacular apparatus is situated exactly on the summit in the *Pedicellinæ*, on the slightly concave ventral side in *Loxosoma*; that part of it which in the former presents the appearance of a sac with a central orifice, in the latter assumes the form of a hood, fastened under the chin and drawn over the head. A tendency, however, towards a similar conformation is recognisable in the *Pedicellinæ*, whose two sides, the ventral and dorsal, are far from symmetrical. This unsymmetrical habit is already visible in the bud; it enters into the primitive plan of the *Pedicellinæ*, but in them it is obscurely indicated, whilst in *Loxosoma* it exists to such an extent as to involve the displacement of the tentacular corona.

The *Loxosomas* are further distinguished by a certain delicacy in the entire constitution both of the organs and tissues.[1] The

which I am indebted to Dr. M'Intosh, the line of separation between the body and the stem is very strongly marked, and there is a slight indentation where they join. In another species from the Gulf of St. Lawrence, the body seems to pass as it were into the stem, without any apparent line of demarcation between them. In no case, it would seem, is the separation between body and peduncle so complete as in *Pedicellina*, in which genus the fall and subsequent renewal of the body are of frequent occurrence.—*Transl.*

[1] This may, perhaps, prove to be a somewhat hasty generalisation. At any rate, I can adduce one very notable exception. A species of *Loxosoma* occurs on the scales of *Lagisca* from the Gulf of St. Lawrence, which is remarkable for the stoutness of its habit, and for the thickness and toughness of the body-wall, which is more or less covered, like the stem of *Pedicellina echinata*, with spinous processes. I owe to Dr. M'Intosh's kindness the opportunity of examining this very interesting form, which I hope shortly to describe in detail.—*Transl.*

Pedicellinæ, on the contrary, are strongly built; their movements are energetic, abrupt, and even violent, as compared with the slow and languid undulations of the *Loxosoma*, a fact which is explained by the difference in the muscular fibres of the two. The cuticle of the former is much thicker and stouter, the hypoderm more highly developed, all the organs are more distinctly defined, and there is much less transparency than in *Loxosoma*. The same differences are observable in the embryos of the two forms.

A very close relationship between the two genera must be admitted, notwithstanding these differences and others which might be mentioned in the buds and embryos. With respect to the former, though differently placed in the two genera (on the body of the polypide in one and on the stolon in the other), it is probable that the course of development is the same in both.

The difference in the gemmation, which corresponds, no doubt, with the mode of attachment, may be regarded as an adaptation fitting the *Loxosomas* for their semi-parasitic life; but the Author remarks that the fact is not explained by the mere use of the word "adaptation." The *Pedicellinæ* attach themselves to plants and various submarine bodies by stolons, on which the *gemmæ* are developed. The *Loxosomas* are solitary animals, and adhere by the foot or base of the body, while the buds originate from the skin of the body. But if in the case of those species of *Loxosoma*, which attach themselves to annelids, &c., with a contractile skin, the habitat accounts for the absence of a stolon, which would be continually broken by the contractions of the animal, it is otherwise with those that are found on the stationary *Bryozoa*, whose polyzoaries offer a more rigid surface than that of the sea-weeds infested by the *Pedicellinæ*.

The *Loxosomas* are said to pullulate on the glass of aquaria in Naples. If they are adapted to a semi-parasitic life, how comes it that they abandon this life by fixing themselves in the same way as upon the animal on a smooth and lifeless body?

In the embryo of the two genera, the Author recognises similarity of general plan combined with profound differences in detail. The more matured condition, so to speak, of the *Pedicellina* embryo has been referred to. Other points of difference may be found in the more perfect development of the intestine in the latter, the presence of rudimentary generative organs, eye-specks, and perhaps of the central nervous system, which is entirely wanting, it would seem, even in the adult *Loxosoma*, and in the absence of the spectacle-organ, which is replaced by two highly contractile lateral processes, ciliated at the extremity.

The Author does not share the doubts that have been ex-

pressed respecting the affinities of *Pedicellina* and *Loxosoma.* He not only regards them as undoubtedly *Bryozoa*, but more than this, as the prototypes of the ordinary *Bryozoa*, and holds that the primitive structure has been modified in the latter by their associated life and by the formation of the cœnœcial structures in which they are imprisoned.

It may be assumed, he thinks, that every primitive animal must have been free, a locomotive individual, and that the fixed state, as well as the colonial life, are secondary conditions acquired in the course of generations. If proof were needed, it might be found in the fact that the young of all fixed and social animals are free. Now all the known *Bryozoa* are fixed, and a large majority of them take the form of colonies. The only kinds with isolated individuals are the *Pedicellinæ*, the *Loxosomas*, and the *Urnatellæ*, of which the latter are very imperfectly known. *Loxosoma* evidently exhibits the most primitive condition amongst recent *Bryozoa*. The *Pedicellinæ* have made an advance towards true colonization by the development of a stolon, producing buds.

The assumption of the colonial condition must bring with it modifications of the primitive organisation, whilst the chief features of the type would remain more or less apparent. The formation of ectocysts, of cells in which the polypides are contined, the development of retractor muscles, and the change in the position of the anal orifice, are, in the Author's opinion, the only important characters that distinguish the ordinary colonial *Bryozoa* from the isolated forms, the latter in their turn possessing a distinctive character in the stem on which the body is mounted.[1] The structure and the arrangement of the tentacles around the mouth, the conformation of the digestive canal with

[1] Allman regards the stalk of *Pedicellina* as homologous with the posterior part of the cell in the unstalked forms of *Polyzoa*. "It is simply," he says, "this portion of the cell become so much constricted as to be no longer capable of containing the polypide, which is in consequence pushed onwards into the wider portion which now constitutes the proper cell." ('Freshwater Polyzoa,' p. 22.) We can hardly speak of a cell, with any propriety, in the case of *Pedicellina*, in which the body-wall lies close upon the internal organs, and does not constitute a sac-like dwelling, within which the polypide has the power of moving freely. But the observations of Barrois on the embryonic development of the *Entoprocta* show that Allman's view is essentially correct. After the development of the *Gastrula*, he describes a stage in which the embryo is distinctly divided into three segments. Of these the middle constitutes eventually almost the whole of the skin and its contained endoderm the digestive canal; the posterior segment gradually dwindles away, and at last, with its portion of endoderm, forms merely a small button-like prominence at the base of the larva, which bears a few stiff setæ. The stem, according to Van Beneden's observations, is formed by the prolongation of this basal prominence. It should be added that Vogt has not noticed a similar stage in the case of *Loxosoma*.—*Transl.*

its characteristic bend, remain absolutely the same. The gemmation need not be taken into account, for amongst the ordinary *Bryozoa* two very different types prevail, while in all cases the bud is formed out of the same tissues. Lastly, the form of the embryos and their development must be studied much more in detail before any conclusion can be based upon them. M. Barrois, indeed, has attempted to reduce all the varying embryonic forms of the *Bryozoa* to a single type, and the very attempt shows at least the possibility of such a reduction.

In the present discussion, the nervous and reproductive organs are not in question, for we find them varying even in the most nearly allied species. There remain, therefore, only the (distinctive) characters mentioned above, the adjuncts of the colonial condition, and the altered position of the anus.

Of these, the first need not be taken into account. In all cases we do not hesitate to associate in the same class simple and compound forms; we do not pretend that the *Actiniæ* should be separated from the *Anthozoa*, or the simple Ascidians from the *Clavelinæ*.

The only differential character, therefore, of any importance will be the position of the anal orifice, on which Nitsche's proposed division into *Ectoprocta* and *Entoprocta* is founded, a division which the Author fully adopts. At the same time he would not lay so much stress on this character as to make it a ground for the complete separation of the two series. Both are equally *Bryozoa*; the position of the anal orifice cannot separate them, especially as the change is really in the situation of the tentacular crown and not of the anus. The latter, indeed, occupies, amongst all the *Bryozoa, Ectoprocta* and *Entoprocta* alike, the same position opposite to the mouth; but whilst in the latter the tentacular crown surrounds the two orifices, amongst the former it only encloses the oral.[1]

[1] I have already referred to the difference in the plan of development by which the bud of the *Entoprocta* is distinguished from that of all the other *Polyzoa*, so far as it is known. The peculiarities in the structure and history of the embryo also seem to me to be very important and full of significance. M. Barrois, indeed, has shown that in all the types of embryo the early stages are identical, and he considers that a primitive form may be demonstrated for the group of the *Polyzoa* from which all the known larval modifications are derived. However this may be, it must be admitted that the direct passage of the larva into the perfect animal, which seems to distinguish the *Entoprocta*, and the peculiarities of the embryo, which involve a distinct type of structure in the adult polypide, are points of the highest interest and of great systematic value. Amongst the ordinary *Polyzoa*, so far as the history of their development is known, the larva undergoes a dissolution of its organs after attachment, and assumes the form of a cyst or cell enclosing a mass of formative material, and the polypide is produced *within this* cell by a process of gemmation. In Pied-

The genus *Loxosoma* may be thus characterised :—

Polypides solitary, attached to a contractile stem ; tentacular crown on the ventral side of the body ; buds produced on the body.

The Author recognises the following species, which he ranges in two groups :

Species with a pedal gland—

I. *Loxosoma Neapolitanum*, Kowalewsky.

II. *L. raja*, *cochlear*, and *singulare*, Oscar Schmidt, which are probably only different states of one and the same species.

Species without a pedal gland—

III. *L. Kefersteini*, Claparède. With numerous buds.

IV. *L. singulare*, Keferstein. Stem terminating in a circular disc. Buds never exceeding two in number.

V. *L. phascolosomatum*, C. Vogt. Stem pointed below like the nib of a pen. Never more than two buds.[1]

cellina, and probably in *Loxosoma*, the larva attains a form which approaches very near to that of the adult animal ; its internal organisation is conformed to the type of the adult, and a few comparatively unimportant changes suffice to transform it into the polypide. Its structure determines that of the polypide. Its large contractile mantle, continuous with the body-wall, and *enclosing the whole anterior extremity of the body*, forms the sac-like or hood-like vestibule of the polypide, into which both orifices of the digestive canal almost of necessity open. Within the border of this mantle (or extension of the body-wall) the tentacles are developed, and of course surround *both* apertures. In this position they are necessarily non-retractile, and their movements, which are very limited, depend on those of the sac to which they are attached.

These peculiarities in the developmental history and the modification of the structure of the polypide which they involve are, so far as we know at present, confined to the *Entoprocta*. They (and not the mere position of the anal orifice, as Vogt contends,) separate this group broadly from the rest of the *Polyzoa*, and abundantly justify us in regarding it as a distinct *sub-class*.—*Transl.*

[1] As I have mentioned, one or two new species have occurred to me, and now that attention is directed to the tribe we may expect that many more will be discovered upon the annelids, to which the *Loxosomas* principally attach themselves.—*Transl.*

On the Minute Structural Relations *of the* Red Blood-corpuscles. By Professor Arthur Boettcher, in Dorpat (with Plate XXIII).

Translated from a paper in 'Archiv. für Microscopische Anatomie,' Bd. 14.

Elsewhere I have communicated the fact that a *nucleus* can be demonstrated in the red blood-corpuscles of mammalia, by treating them with alcohol and acetic acid (*Mémoires de l'Académie Impériale des Sciences de St. Petersbourg*, vii série, t. 22, No. 11). On pursuing these investigations I came upon a method which affords a very clear insight into their structure. I have also sent a short report of this to the above-mentioned Academy (Bulletin of January 11th, 1877). In the treatment with acetic acid a distension of the blood-corpuscles easily occurs, which may spoil what was already gained by the hardening in alcohol. This inconvenience I have now managed to avoid, and I propose to give here an accurate description of the results obtained in regard to the structure of the red blood-corpuscles by means of this new method.

Fifty parts by volume of alcohol of 96 *per cent.*, which is saturated with corrosive sublimate, are poured on to one part of blood, care being taken that a rapid diffusion of the blood-corpuscles in the fluid takes place. For this purpose I have used blood defibrinated and deprived as much as possible of serum, and also (in experiments on animals) blood taken directly from a vein.

As soon as the blood-corpuscles enter the alcoholic solution of corrosive sublimate it is found that *they are deprived of their colouring matter* (*hæmatin*) *without the albuminous body, which is combined with it, becoming dissolved.* The blood-corpuscles therefore remain intact, and are merely deprived of the red colouring matter, which hinders the observation of their structure. The former was the case indeed on treatment with absolute alcohol, but the subsequent decoloration with acetic acid was then always necessary, which exerts the disturbing action already mentioned. By the addition of corrosive sublimate to the alcohol we ensure that both actions take place simultaneously: the blood-corpuscles are preserved, and become at the same time completely colourless.

By repeated agitation the action of the alcoholic solution of corrosive sublimate on the red blood-corpuscles can be advantageously assisted. If the latter are then allowed to subside, the sediment is no longer red, but more or less pale, and the column of perfectly clear fluid above it appears of a dark reddish-brown colour. *Complete decoloration of the red blood-corpuscles*

takes place in about twenty-four hours, but the process can be much accelerated by renewing the solution of corrosive sublimate. I preferred, however, before submitting the blood-corpuscles to further operations for the purpose of histological investigation, to leave them in the solution of corrosive sublimate for forty-eight hours.

At the expiration of this time the latter is decanted from the sediment, which has a grey appearance, and is replaced by pure alcohol. The blood-corpuscles having been thoroughly washed with this by agitation, are allowed to remain in it for at least twenty-four hours. The alcohol is then simply decanted and replaced by water.

The blood-corpuscles which sink to the bottom now represent a white mass, which has a slight tinge of grey and somewhat the appearance of pus. They have entirely lost their colouring matter, and have become so capable of resistance that they are no longer acted on by water. I have let them stand in it for eight days or more without being able to notice any change in them.

The subsequent treatment with water offers many advantages for the microscopical examination of the blood-corpuscles, and is of especial service, when artificial staining is undertaken, if for that purpose alcoholic solutions of the colouring matters are not used.

The structural relations, which will be immediately considered, are already partly visible in the decolourised blood-corpuscles. They stand out more clearly, however, after artificial staining, for which purpose I have employed chiefly carmine, but also eosine, hæmatoxylin, and picric acid. All these colouring matters are available; the carmine, however, allows the different components of the blood-corpuscles to be most easily recognised by means of the various shades of colour.

The blood-corpuscles now about to be described were treated according to the method given above.

I. *The Red Blood-corpuscles of Man.*

Whereas these, in the fresh state, as is well known, strongly resemble one another, after having been in the alcoholic solution of corrosive sublimate, and being thus deprived of their colouring matter, they appear extremely varied, and present great difference in regard to their composition. They may, however, be divided into the following distinct classes:

1. *Blood-corpuscles which appear homogeneous and shining* (Fig. 1).

These do not usually collect in heaps, but swim about free in the fluid. Their shape is generally changed in a remarkable manner. Their form, namely, as a rule, is not even tolerably

definable, but they appear very irregularly bounded and provided on the surface with all sorts of elevations and depressions (*a*, *b*). Nothing is seen besides the perfectly colourless mass which refracts light strongly.

It is very seldom that the disk-form is found represented among these homogeneous colourless blood-corpuscles (*c*). It shows then, as before the decoloration, a shallow depression in the centre and the effects of light and shade dependent on it.

More frequently mulberry shapes are met with, which appear furnished on the surface of the more or less globular mass with processes, sometimes coarse and scanty, at other times finer and more numerous (*d*, *e*). Each one of these processes is as homogeneous and highly refractive as the bright colourless substance from which it arises. We have here therefore the same *colourless mulberry and horse-chestnut shapes* which I had previously obtained from the red blood-corpuscles of the cat by treating them with aqueous humour (*Archiv für Path. Anat.* vol. xxxix, plate ix, figs. 1—5).

Amongst the blood-corpuscles belonging to this group I must also mention those which possess on their surface a peculiar striation. In blood-corpuscles of very different forms (as is indicated in the drawings fig. 1, *f*, *g*, *h*, *i*, *k*), there is seen on the shining surface a series of parallel transverse striæ (*f*); in other cases the blood-corpuscles appear notched like a shell with fine indentations, running in curved lines, between which equally regular elevations occur (*g*, *h*, *i*). Sometimes these are especially fine and converge from the two sides to the median line, or they form a radiate figure which proceeds from the centre into the colourless homogeneous substance of the blood-corpuscle (*k*).

Sometimes I have also observed the following form. The blood-corpuscle had almost assumed the shape of a fungus, and become divided into two parts, still connected, although separated from each other to a certain degree. The chief mass formed a concavo-convex disk, presenting the homogeneous shining appearance described above. The part joined on to the concave surface consisted of a number of filaments, also of bright aspect, which at one end were sunk into the disk and at the other end blended with one another (*b*).

I did not wish to omit drawing attention to the above forms, as I do not consider them accidental and unimportant, but think I can prove that they are intimately connected with the internal organisation of the red blood-corpuscles about to be described, and must be considered as derived from these.

2. *A second group of blood-corpuscles, which is very largely represented, is characterised by the fact that two substances can be distinguished in them, viz. a homogeneous shining* cortical layer

and a granular mass in the interior. The latter is more darkly stained by carmine and eosine (fig. 2).

The blood-corpuscles belonging to this group are usually collected together in heaps, or rather spread out side by side in a thin layer. They are mostly spindle-shaped, all possible varieties being represented, both long and narrow and short and wide (*a, b, c, d, e, f*). At first sight these blood-corpuscles remind one of many cell-forms from the embryonic connective tissue; any one, therefore, seeing them for the first time would not easily imagine that he had red blood-corpuscles before him, so different is their appearance to that usually presented by these structures.

The adhesion of these corpuscles to one another is explained by their being held together by traces of coagulated plasma or serum, according to whether fresh or defibrinated blood has been used for the experiment, and their inclusion in a coagulating mass may not be without its influence on the formation of the spindle shape. A greater influence on the formation of this shape is probably due to the fact that, at the moment when the solution of corrosive sublimate acted on the blood-corpuscles, they were stretched by violent agitation of the fluid. I know of no other reason why these blood-corpuscles, whilst only an extremely small quantity of coagulated albumen lies between them, should nearly always all of them appear extended into spindles *in one and the same direction*.

Besides these spindle-shaped corpuscles, more rarely elliptical and spherical blood-corpuscles (*h*) are seen, in which two constituent parts can also be distinguished.

The *form of the central granular mass* usually adopts itself to the shape of the whole corpuscle (*f*), *i.e.* in the long spindle shapes it is found much elongated (*a b*), and in the globular blood-corpuscles collected into a ball (*h*). This is, however, often not the case, but the granular substance appears contracted in the centre of an elongated blood-corpuscle (*e*). Once I found it denuded and projecting from the cortical layer on one side of the spindle (*g*).

If now in all these blood-corpuscles *two* substances can be distinguished, a homogeneous cortical layer, and a granular substance enclosed within it, it is natural to look upon the latter, in the cases in which it has a circular or oval outline, as the nucleus of the blood-corpuscles (*d, e, g, h*). But the relations to be immediately mentioned permit of a farther distinction, which causes their structure to appear in a different light. The circumstance alone that the central granular mass frequently constitutes a comparatively large part of the red blood-corpuscles, is sufficient to lead to the supposition that it does not consist of

the nucleus only. Further, it frequently appears elongated to an extent (*a*, *b*) that does not usually occur in nuclei, and finally a peculiar transverse striation (*s*) is often seen on it, which points to special structural relations.

I will, however, not spend more time over these matters, which contain much that is still obscure. There are in every preparation numerous examples, which afford a clue to the right understanding of the peculiarities here met with in the granular substance of the red blood-corpuscles.

The least ambiguous forms, which at once indicate the structure, are represented in figs. 3 and 4. Those in the former figure are frequently seen, those in the latter more rarely. Let us, therefore, confine our attention in the first place to the former.

Amongst them we find blood-corpuscles of irregular form, whose granular substance is accumulated more or less to one side of the interior, and throws out numerous radiating processes in the shape of finely granular threads into the adjacent homogeneous cortical layer (fig. 3). The former, with all its processes, is more darkly stained with carmine or eosine than the latter. This property, as well as the morphological relations described, are so characteristic that the granular substance is easily recognised as a ball of protoplasm surrounded by the homogeneous cortex. Every doubt, however, with regard to the correctness of this interpretation, is removed by a consideration of the blood-corpuscles represented in fig. 4.

3. *Blood-corpuscles, in which three parts can be distinguished:* (*a*) *the bright homogeneous cortical layer;* (*b*) *the granular protoplasm, which stains more deeply with carmine;* *and* (*c*) *a clear nucleus, enclosed in the latter, and containing a bright nucleolus* (fig. 4).

With regard to the homogeneous cortical layer of these *cells*, I have nothing to add to what has been already said about it. The enclosed protoplasm is very variously shaped, being at one time collected into a ball (*a*), at another time more extended (*c*), and, again, in other cases provided on all sides with radiating processes (*b*). Finally the nucleus, when I could distinguish it clearly, had always a circular outline, and could be recognised as a bright homogeneous spot in the red granular protoplasm. Whether it had not also become stained by the carmine could not with certainty be ascertained; at all events, the staining, if present, was very slight, which rendered the contrast between it and the red-stained protoplasm so much the more conspicuous. The bright nucleolus was also in all these cases characteristic of the nucleus, and no one can deny that in the red blood-corpuscles

represented in fig. 4 it has been possible to demonstrate the attributes of a cell to an extent hitherto unlooked for.

After I had, by means of the advantages possessed by the above-described method, managed to distinguish the nucleus of the red blood-corpuscles from the surrounding protoplasm, it was natural that those forms, in which within the homogeneous cortex only a granular substance stained red by carmine is seen, should receive another interpretation. It is evident that the central mass of the blood-corpuscles represented in fig. 2, *a*—*g*, cannot be the nucleus, but only the protoplasm. It may be taken for granted that the former cannot be detected in them only, because circumstances are not favorable for seeing it. Probably the mass of the granular substance simply prevents its being seen. The same may be asserted of the forms represented in figs. 3 and 5; but with regard to these I have something to add which appears important in order to understand them rightly.

The processes of the protoplasm, as already mentioned, may be considerably developed and extended to some length (fig. 3). In other cases, however, they are short and of capillary fineness (fig. 5, *a*, *b*, *c*). The central granular ball then appears as if invested with fine bristles on all sides; this occurs both in the more compact forms (*a*) and also in the thin elongated spindles (*c*). It also happens sometimes that the processes are conical, which causes the protoplasmic mass inside the homogeneous cortex to assume accurately the aspect of a mulberry-shaped blood-corpuscle (*d*). It also appears that its surface is not always similar on all sides, but one side may be beset with papilla-like elevations, whilst the other appears simply granular (*e*).

After all, it may be considered certain that the protoplasm of the red blood-corpuscles, when these are introduced into a concentrated alcoholic solution of corrosive sublimate, sometimes becomes rigid with extended processes, and at other times appears in a contracted condition, as in fig. 2. If, now, in such blood-corpuscles a *transverse striation* of the protoplasm can be frequently recognised (fig. 2, *c*) this must be referred, I believe, to imperfectly developed processes, which, running in a particular direction, cannot be recognised as such in a certain position of the blood-corpuscles, but give to the granular part a striped appearance. The drawings *a*, *b*, *c*, in fig. 5 seem to me to justify this conclusion, for with inferior lenses I see in these blood-corpuscles nothing more than a striation of the protoplasm.

The relation of the protoplasmic portion to the homogeneous cortical layer is also deserving of especial consideration. In reference to this, it is necessary to point out, in the first place, that in a large proportion of the blood-corpuscles the *nature of the surface* is

independent of the form of the protoplasm, i.e. the surface may appear perfectly smooth, although numerous long protoplasmic processes radiate into the cortical layer (compare fig. 3, fig. 4 *b*, fig. 5). *In other cases, however, the cortical layer appears to follow the processes of the protoplasm,* adapting itself to the elevations and depressions, and by this means uniformly surrounding the radiating protoplasmic body. This must, I think, be inferred from the different forms, which appear indented in a very peculiar manner (fig. 1). The stripes and swellings on the surface in *f, g, h, i,* and *k* are easily understood if we suppose that processes situate in the interior of the protoplasm, as we have already seen them in numerous other blood-corpuscles, give rise to the protrusion or indentation of the cortical layer. Still more does the drawing (*l*) in fig. 1 suggest this interpretation. In this case radiating filaments are actually visible, but they have a homogeneous structure, and are highly refractive like the cortical layer. This peculiarity might, however, be explained by supposing that they appear still surrounded by a layer of the cortical substance, after the protoplasmic body has become pushed on to one side and almost isolated. Farther, a companion of fig. 1 *e* with fig. 5 *d* renders still more probable the supposition that the protoplasmic processes can exert an influence on the form of the surface. Fig. 1 *e* represents a decolorised mulberry-shaped blood-corpuscle of a bright homogeneous aspect. In fig. 5 *d* we find the same mulberry shape in the protoplasm within the homogeneous cortex. Both blood-corpuscles have been exposed to the solution of corrosive sublimate; but either they possessed on entering the fluid a different relative arrangement of the two parts, or it may have happened that in the one case (fig. 5 *d*) the action was less momentary and that the protoplasm had time to contract into a sphere beset with protuberances, whereas in the other case the blood-corpuscles (represented in fig. 1 *e*) immediately stiffened in the mulberry forms. In the latter case the general spherical form of the blood-corpuscle and the numerous projections on its surface may have rendered the similarly-shaped central ball of protoplasm very difficult to be seen. It appears to me, therefore, that the possibility at least must be granted that the homogeneous cortical layer is bulged out mechanically by the processes of the protoplasm, and is made to envelope them uniformly.

If this is not the case, however, in many blood-corpuscles, as we have seen, but the cortical layer remains smooth on the surface, although it is traversed by *visible* processes of the protoplasm, this may be caused by various circumstances. It is conceivable that in these cases the processes of the protoplasm are either small (fig. 5, *a*, *b*, *c*) and too insignificant to exert

formative influence on the comparatively thick cortical layer, or that, as the drawings in fig. 3 actually show, the protoplasm has become collected on the one and the cortical layer on the other side of the blood-corpuscle, and that in this case also, because the processes radiate into a layer of cortical substance of considerable thickness, the latter does not accommodate itself to the shape of the former, in spite of their length. Finally, it is necessary to take into consideration the circumstance that the amount of protoplasm varies much in individual blood-corpuscles, and that in proportion as it diminishes the homogeneous substance increases in quantity. I have already shown this by another method, both in the blood-corpuscles of amphibia and in those of mammalia ('Virchow's Archiv,' vol. xxxvi, pp. 367 and 377). The same differences which are there mentioned are met with in the treatment of red blood-corpuscles by an alcoholic solution of corrosive sublimate.

Although clearly visible in many blood-corpuscles, the sphere of protoplasm is in others equally invisible. The blood-corpuscles remain after decoloration, and in spite of staining with carmine quite homogeneous, even when they are not spherical, but perfectly flat (fig. 1, *a*, *b*, *c*). Although it may be concluded from this that these blood-corpuscles enclose very little or no protoplasm, minute investigation enables us to bring forward a stronger proof of the accuracy of this supposition.

Amongst a large number of blood-corpuscles submitted to examination some will always be found in which the nucleus with its sharply marked outline is perceived within the homogeneous substance, but no granular protoplasm can be seen in its vicinity (fig. 6). If in these blood-corpuscles any protoplasm were present, it must be easily recognised, especially after staining with carmine, as in fig. 4, for it appears scarcely possible that where the more deeply situated and less perceptible nucleus with its circular outline is visible, the more easily distinguished layer of protoplasm surrounding it could remain hidden. In the nuclei of these perfectly homogeneous forms I have sometimes found a nucleolus present (fig. 6, *a*); at other times it was absent (*b*).

Before concluding my communication on the human blood-corpuscles I have to report *a case of poisoning by corrosive sublimate*, in which I was able to examine the blood immediately after the *post-mortem* examination. The porter of the Pathological Institution took a large draught of the alcoholic solution of corrosive sublimate in question, and died from the effects of it on the fourth day. Although the autopsy did not take place till thirty-six hours after death, the body presented no perceptible signs of decomposition. It is necessary to enter here into the

details of the examination. It will suffice to mention that everywhere, although the corpse was still fresh, a very remarkable saturation of the tissues in the neighbourhood of the blood-vessels with the colouring matter of the blood was noticed. With regard to the stomach in particular, there was found on its posterior wall, running from the cardiac end to the fundus, a dark-red tract of mucous membrane of a hand's breadth, in which both the large blood-vessels were strongly marked by a sanguineous imbibition of their neighbourhood, and also the intervening islands of mucous membrane were of a diffuse red colour, the intensity of which was further heightened by numerous scattered points of extravasation. A corrosive destruction of the mucosa had not taken place, nor was there any *post-mortem* softening of the coats of the stomach. Still more remarkable was the fact that also on the outer surface of the stomach the larger branches of the blood-vessels were distinctly mapped out by the sanguineous imbibition of the tissues immediately surrounding them, like the veins in the skin of a corpse that has been frozen. The bloody discoloration of the transudations in the cavities of the pleura, peritoneum, and pericardium was also very considerable. The pericardial fluid, which amounted to about one ounce, was perfectly clear and transparent, but at the same time as dark red as a tolerably concentrated solution of hæmoglobin.

Having ascertained these facts, and knowing as I did the above-described action of concentrated solutions of corrosive sublimate on the red blood-corpuscles, I was the more anxious to proceed to an examination of the blood, which I took from the right ventricle of the heart. And, in truth, a very remarkable change in the blood of the corpse became evident. Although the blood, as mentioned, presented no signs of decomposition, and could not at the temperature then existing have been frozen, immediately after removal it presented the appearance of blood imperfectly clarified by freezing. In thin layers it was perfectly transparent.

On microscopical examination I found no inconsiderable number of red blood-corpuscles, but they were almost all exceedingly pale, and were neither disk- nor mulberry-shaped, but presented mostly a spherical form, or one approaching to it. *Moreover, in many of them without further treatment a nucleus could be seen,* which possessed a spherical form and sharp outline, and was somewhat granular in character (fig. 7, *a*, *b*, *c*, *d*). In the neighbourhood of the nucleus was a greater or less quantity of colourless granular substance (protoplasm), but the granules composing it had separated, and were very much scattered.[1]

[1] The faded spherical blood-corpuscles with the nucleus and scattered granules of protoplasm in their interior reminded me forcibly of the pale

I noticed a more compact protoplasm in the less numerous cup-shaped corpuscles, in which it projected from the concave surface (fig. 7, *e, f*). In this case the nucleus was not visible.

Besides the blood-corpuscles described, considerably smaller and darker homogeneous forms, sometimes spherical, at other times furnished with a central depression, were present in smaller numbers (*g*).

Eighteen hours later the blood, which during that time had stood in a well-closed stoppered bottle at the ordinary temperature of the room, although it exhibited not the least smell of decomposition, had become perfectly lake-coloured. Only in a few small soft coagula at the bottom of the vessel could I now succeed in finding red blood-corpuscles, and these presented the same properties as those I have already described.

On the whole the changes in the red blood-corpuscles appear to play an important part in poisoning by corrosive sublimate. On the other hand, it results from the preceding observation that the finding of nucleated blood-corpuscles (so-called transition-forms) in one or other part of the vascular system does not yet justify conclusions with regard to the importance of the respective organs in the formation of red blood-corpuscles.

The red blood-corpuscles can, as we have seen, be transformed by partial decoloration into the so-called transition-stages, which at present are indistinguishable from the embryonic blood-corpuscles.

II. *The Red Blood-corpuscles of the Camel.*

In my first treatise on the red blood-corpuscles of the camel (*Mémoires de l'Académie*, &c., p. 13), I have shown that the nucleus of these corpuscles can be demonstrated by different methods. The supposition of various authors that it can at once be perceived, like the nucleus in the blood-corpuscles of the frog, is, however, not correct. Rollet declares that the blood-corpuscles of the camel are not provided with a nucleus any more than those of man and the other mammalia (Stricker's *Handbuch der Gewebelehre*, p. 275). I was the first who succeeded in demonstrating the nucleus. But I was only able to see it clearly within the homogeneous substance surrounding it, after the blood-corpuscles had parted with a portion of their colouring matter by the occurrence of decomposition in the blood. The next step was, therefore, to ascertain by experiment whether the treatment of the camel's blood-corpuscles with an alcoholic solution of corrosive sublimate would produce a better result than the decoloration by alcohol and acetic acid. The colouring

yellow-coloured transparent blood-corpuscles of the young larva of the frog. (Compare Virchow's 'Archiv, vol. xxxvi, pl. x, fig. 20.)

matter cannot be extracted by corrosive sublimate from red blood-corpuscles which have been preserved in alcohol. It was, therefore, of great service to me that, by a lucky chance and by the kindness of Professor A. Rosenberg, I was soon again possessed of fresh camel's blood, when the animal which I had already used once was purchased by the Dorpat Veterinary Institution.

The blood of this animal, after being defibrinated, was treated in the manner above described. My statements with regard to the camel's blood were then confirmed in every respect. *Of the blood-corpuscles decolorised by the alcoholic solution of corrosive sublimate, at least one half show two component parts*—a homogeneous cortical layer and a granular mass situate in the interior, which stains more deeply with carmine (fig. 8, *a*, *b*). This is the granular protoplasm, which is accumulated round the nucleus. Processes of the protoplasm, presenting the varied appearances observed in the blood-corpuscles of man, I have not found in those of the camel. This may be due to accidental circumstances, which cannot at present be determined. The important fact, however, in the structure of the mammalian blood-corpuscle is here to be recorded, that within the homogeneous cortical layer a second constituent part can be demonstrated, which hitherto no one has seen. *In the interior of this, just as in the protoplasm of the red blood-corpuscles of man, is situated a nucleus.* Any one unaccustomed to examining red blood-corpuscles would be inclined to consider the central body, represented in fig. 8, *a* and *b*, as the nucleus. But a closer acquaintance with the object teaches that two things must here be distinguished. The nucleus possesses, as I have already proved, a membrane with a double contour, is less granular, and encloses usually a nucleolus. Neither does it become coloured by carmine, like the protoplasm. When surrounded by the latter it is not always seen, but in other more favorable cases the sharply defined ellipse is perceived within the granular mass (fig. 8, *c*). This nucleus then appears to agree accurately both in form and size with the nuclei, which I have isolated by different methods from the blood-corpuscles of the camel.

What I was therefore obliged to take for granted as the cause of the non-visibility of the protoplasm and nucleus has proved to be quite correct. The homogeneous cortical layer of the camel's blood-corpuscles is comparatively thick, and at the same time very highly refractive. Observation is thereby impeded. And if the blood-corpuscles, which have become rigid in concentrated alcohol are decolorised by acetic acid, the advantage gained by the decoloration is again lost by the swelling which takes place. The blood-corpuscles then indeed appear colourless, but are

apparently quite homogeneous. The concentrated alcoholic solution of corrosive sublimate is alone able to reveal in the blood-corpuscles of the camel the structural relations which I had already become acquainted with in the human blood-corpuscles by the same method.

III. *The Red Blood-corpuscles of the Frog.*

After I had proved in mammalian blood-corpuscles the great advantages which are afforded by the method described, I could not refrain from applying the same method to those blood-corpuscles which have hitherto alone been regarded as nucleated. I have, however, not yet been able to examine in this respect all classes of animals with distinctly nucleated elliptical blood-corpuscles.

Whilst reserving to myself farther communications in regard to those of birds and fish, I shall at present only make some statements with regard to the appearances which the blood-corpuscles of the frog present when they have been treated with an alcoholic solution of corrosive sublimate. I can be the more concise in my remarks as the interpretation of the structural relations meets with much fewer difficulties in regard to prevailing notions on the subject. The drawings which I have added will also materially assist in understanding them.

That a granular protoplasm is collected round the nucleus of the frog's blood-corpuscle, and that filaments radiating outwards from it, can be demonstrated in many blood-corpuscles, is by no means generally admitted. It may even be asserted that with the exception of the few observers who have devoted special attention to this subject, no one has taken notice of the observations referring to it, which are, it is true, still incomplete. The doctrine of "Stroma" has also hindered the advance of our knowledge of the structure of the blood-corpuscles. As far as I know, only Hensen, myself, and Kollmann have investigated the subject with any minuteness. Hensen first reported on the appearances obtained by crushing fresh blood-corpuscles of the frog. I then confirmed his statements, and described further the peculiar forms which a five *per cent.* solution of tannin produces in the blood-corpuscles of the salamander. From these observations it was inferred that around the nucleus of the amphibian blood-corpuscles a mass of protoplasm is collected which radiates in the form of filaments into the homogeneous red substance. I laid especial stress on the fact that the blood-corpuscles are not all similar, but that there are many in which the nucleus appears surmounted with only the colourless granular matter, and again, others in which the latter cannot be demonstrated at all. I feel obliged to make these preliminary remarks

because the experiments with the alcoholic solution of corrosive sublimate confirms in a most gratifying manner the results which were obtained by an entirely different method. I refer the reader at once to the drawings in figs. 9, 10, and 11. The first two figures are taken from uncoloured preparations, after the blood-corpuscles had been purified from corrosive sublimate by washing, first with alcohol and then with water; fig. 11 is after staining with carmine.

The peculiarity of the drawings is sufficient to convince any one that we have not here to do with accidental forms which have been artificially produced by the method of treatment, but with details of organisation which have been obtained by a sudden solidification of the substance of the corpuscles. In the momentary action which causes the temporary condition to remain a permanent one lies, independently of the decoloration which takes place, a great advantage, which the concentrated solution of corrosive sublimate possesses over all other reagents which have as yet been employed in the study of the red blood-corpuscles. What strikes one as peculiar in the treatment of frog's blood-corpuscles by corrosive sublimate is the behaviour of the protoplasm. *The homogeneous cortical layer* (hæmoglobin) presents differences only in regard to the quantity which belongs to individual blood-corpuscles. The outline remains even, and the shape of the blood-corpuscles is, as a rule, well preserved if the blood be allowed to drop directly from the blood-vessels into a solution of corrosive sublimate kept in motion by stirring (fig. 11). More irregular forms are seen when defibrinated blood is treated in a similar manner (fig. 9). The homogeneous cortex is coloured pale red by carmine and eosine, the protoplasm at the same time becoming much darker. The latter then appears of such varied form that I can only give a general idea of its shape, of which the chief types are illustrated in the accompanying drawings.

The protoplasm appears sometimes collected uniformly round the nucleus (fig. 11, *h*), at other times it is accumulated more to one side of it (fig. 9, *a* and *d*, fig. 11, *a*). It is either provided with only a few processes (fig. 9, *b*) or is arranged round the nucleus in the shape of an elegant star, whose points extend to the margin of the corpuscle (fig. 10, *b*), or else it forms round the nucleus a peculiar lobed figure (fig. 11, *f*). Very often it appears beset on one or all sides with fine hair-like processes (fig. 9, *c*, and *d*, fig. 10, *d*, fig. 11 *a*, *b*, *d*). Then, again, it may represent a sort of network, which either appears distinctly separated from the less darkly coloured cortical layer and more contracted, or else it throws out into the cortex innumerable very fine radiating filaments, so that its processes approach the extreme

periphery of the blood-corpuscles (fig. 11, *e*, *e*, *i*). In this case, therefore, the whole blood-corpuscle is permeated by a network of fine filaments.

Lastly, there are blood-corpuscles in which the form of the protoplasm shows itself, but indistinctly, and merely a darker staining with carmine, and the somewhat granular nature of the centre reveals the collection of protoplasm around the nucleus (fig. 11, *g*). Such blood-corpuscles form the transition to the perfectly homogeneous forms, in which carmine staining shows nothing further than a faintly-coloured mass of uniform character, in which the nucleus lies (fig. 11, *l*). In blood-corpuscles of this sort, which are not stained, the outline of the nucleus is usually indistinct, and on the surface there appears here and there small dark spots, which may be dependent on remains of the protoplasm still present (fig. 10, *a*).

In the *nucleus* of the blood-corpuscles of the frog, after treatment with an alcoholic solution of corrosive sublimate, the same points can be observed as those already known from other observations. It possesses, as was already ascertained by Ranvier, a sharply defined nucleolus; but I have not by any means found it present in all blood-corpuscles (compare figs. 10 and 11). The nucleus is stained by eosine, but not at all, or only very faintly, by carmine.

Relying on the results of the above observations, I think I may be permitted to oppose once more the current views on the structure of the red blood-corpuscles. The doctrine of "Stroma," originated by Rollet, generally accepted, and repeatedly combated by me alone, is incompatible with the facts brought forward.

This so-called stroma is nothing more than a residue of the colourless part of the red blood-corpuscles, varying much in form and extent, which remains after the dissolution of the original structural relations. The appearance and size of the colourless residue depends upon the means which have been employed to dissolve the blood-corpuscles, and upon the intensity with which their action has taken place. Besides this, it is necessary to take into consideration a point which has been entirely overlooked, that the colourless part of the individual blood-corpuscles appears to vary much in size.

The stroma, as it has been displayed by methods hitherto in use, is an *artificial product*, and the ideas of the structure of the red blood-corpuscles resting on it have rendered much more difficult the maintenance of a genetic relation between them and the colourless blood-corpuscles. The developmental connection between red and colourless blood-corpuscles appears to be esta-

blished for the first time, as far as it can be established anatomically, by the observations communicated above.

All methods which have been employed by others in the examination of the red blood-corpuscles, however interesting may be the facts that have been made known by them, have proved insufficient to ascertain the minute structure of the red blood-corpuscles, because they all of them considerably alter and destroy their structure. To these belong the mechanical crushing of the blood-corpuscles, the treatment with electric currents, the application of heat and cold, and the employment of the chemical reagents hitherto in use.

In my first investigations ('Virchow's Archiv,' vols. xxxvi and xxxix) I endeavoured to employ methods which alter the red blood-corpuscles as little and as slowly as possible (blood serum and aqueous humour). Now, I have chosen an entirely different course, since I have aimed at hardening the blood-corpuscles and then extracting the hæmatin from them. I achieved this partly by means of the alcohol-acetic-acid treatment, but still better by means of a concentrated alcoholic solution of corrosive sublimate. Both means employed by me—the decoloration by aqueous humour, and the decoloration by corrosive sublimate—although so different, have led to the same results in regard to the structure of the red blood-corpuscles. If it be, therefore, a question of establishing the advantages these methods possess over those of others, this fact must procure them recognition.

In conclusion I cannot refrain from alluding to the question of the *contractility* of the red blood-corpuscles. As is well known, it was brought forward by Klebs, but was then pretty generally denied; and no doubt correctly in regard to the phenomena of motion, which are exhibited by other cells, *e.g.* the colourless blood-corpuscles.

There can be no question of a spontaneous *locomotion* in the case of the red blood-corpuscles. Motion of this sort has never been observed by any one, for the movements of the mulberry and horse-chestnut (thorn-apple) forms, which rock on individual points, may at once be classed as molecular movements, and left out of consideration.

Neither can the alterations in *form* occurring in the red blood-corpuscles be compared to those of the colourless blood-corpuscles. A constant change in the contour of the corpuscle, and in the arrangement of the individual particles, is entirely absent in the former. When the red blood-corpuscles have assumed a certain form, it appears to remain permanent for a considerable time, even under circumstances in which the colourless blood-corpuscles always change their shape. Changes in

shape are, however, not entirely absent in the red blood-corpuscles. As is well known, the disk shape of the mammalian blood-corpuscle can change into the mulberry or spherical form, and the mulberry-shaped blood-corpuscles can also become spherical. The differences in form occurring in the elliptical blood-corpuscles are much less. Those of the camel appeared to me especially unchangeable. Somewhat more varied is the form of the frog's blood-corpuscles. But all varieties observed in the red blood-corpuscle, and also in the disk-shaped blood-corpuscles of mammalia, remain for a considerable time unchanged. The individual blood-corpuscles are always motionless, and the tranformations which take place in them during long periods of time cannot therefore be compared to the phenomena of contractility observed in the colourless blood-corpuscles.

If, however, as I have endeavoured to show for the red blood-corpuscles of man and of the frog, the protoplasm occurs in such exceedingly varied form, and with such peculiar arrangement as is usually only seen in protoplasm undergoing active movement, one appears justified in questioning whether it does not retain its mobility within the non-contractile homogeneous cortex. Unfortunately the circumstances are so unfavorable that it would be almost impossible to establish by direct observation any movements in the protoplasm of the red blood-corpuscles. This does not, however, preclude the possibility of the protoplasm within the homogeneous case of hæmoglobin being in a state of continuous movement. For it is only in living protoplasm that we are acquainted with such filamentous processes, such discs and such net-like arrangements, and again with such globular accumulations as we have met with in the colourless substance of the red blood-corpuscles. The fact that the object presents such inseparable difficulties, that it is impossible to decide by direct observation whether in the interior of the red blood-corpuscles a movement takes place or not, does not give us any right to deny it. On the other hand, many of the peculiar forms, which I have described in the human blood-corpuscles treated by corrosive sublimate, appear to me to be best explained by supposing that the homogeneous cortex often takes a passive part in the movements of the protoplasm. I would class the hæmoglobin-envelope of the red blood-corpuscles with the capsule of cartilage cells, and with the cellulose membrane of vegetable cells, in so far as these are to be regarded as transformed protoplasm, since, for reasons which I have stated elsewhere, I must consider the cortical layer as the result of a process of development which deprives the blood-cells more and more of their protoplasm, and finally converts them into homogeneous bodies.

DORPAT, *January*, 1877.

CONTRIBUTION *to the* MINUTE ANATOMY *of the* EPIDERMIS *in* SMALLPOX *of* SHEEP. By E. KLEIN, M.D., F.R.S. (With Plate XXIV.)

IN my paper on sheep-pox ("Research on Smallpox of Sheep," 'Philosophical Transactions,' vol. 165, 1874) I have shown that in the thickened epidermis of the primary pocks —*i. e.* those produced directly at the seat of inoculation—a peculiar change takes place in the rete Malpighii, which leads to the formation of what I called a median horny streak. I have shown that in the middle layers of the greatly hypertrophied rete Malpighii smaller or larger groups of epithelial cells are converted into horny, irregular masses, the nuclei of the cells at the same time disappearing. By the confluence of a number of such horny masses there is formed a stratum in the rete Malpighii, which corresponds, in all its characters, to the stratum lucidum, *i. e.* the deep portion of the stratum corneum. By that additional stratum lucidum the rete Malpighii is separated into two sections, a deep one representing the *true* rete Malpighii, and an *upper* or superficial one, situated between the two strata lucida (see 'Philosophical Transactions,' Plate 30, fig. 6; Plate 32, fig. 14; and also this memoir, Plate XXIV, fig. 3). The cells of the latter become, however, gradually homogeneous; their nucleus diminishes in size and also in the power of taking up staining until it is altogether lost; the cell outlines disappear, and the whole mass becomes eventually one with the stratum lucidum. In consequence of this change the two strata lucida, *i. e.* the true stratum lucidum and the additional or median stratum lucidum (median horny streak), become fused into one thick layer. This change I have shown to take place first in the middle of the pustule, and gradually to spread towards the periphery.

In the sixty-ninth volume of 'Virchow's Archiv,' p. 409 (March, 1877), Dr. Unna describes, in the smallpox of man, a structure in the epidermis of the pustule, which he calls "Pockenkörper," and which so closely resembles our *upper* section of rete Malpighii enclosed between the two strata lucida (see Plate XXIV, fig. 3), that I have no doubt the two are in their structure and development identical. Dr. Unna, however, gives a totally different account of the development of the "Pockenkörper" in smallpox of man from the one I gave of the analogous structure in the sheep-pox, and he assigns to the "Pockenkörper" such an importance

in the development of the vesicles of the pustule (which in the case of sheep-pox it does not possess) that I think it necessary to compare more closely his assertions with those given in my memoir.

a. As regards the development, Dr. Unna asserts that in smallpox of man the "Pockenkörper," *i. e.* the superficial part of rete Malpighii enclosed between the two strata lucida (*d* in fig. 3) has been part of the stratum lucidum; he assumes that, in consequence of the morbid infection, the middle part of the original stratum lucidum swells up; its cells become again distinct; their nuclei are visible, and take again to staining, and that this part is now bordered on its lower and upper surface by unchanged stratum lucidum. As the chief reason for this assertion Dr. Unna seems to regard the fact that the "granular layer," which in the normal condition lies underneath the stratum lucidum, is in the pock-epidermis to be found underneath the lower (or median) stratum lucidum.

Now, I am not prepared to make any statement regarding the nature of the different parts of the epidermis in smallpox of man; but as regards smallpox of sheep I can assert that the appearances represented in fig. 3 (see also my first paper on this subject in the 'Philosophical Transactions'), which in their principal parts entirely correspond to the changes in smallpox of man, as described by Dr. Unna, are produced in the manner described by myself, and not in that stated by this observer, viz. that the superficial layer of the rete Malpighii (*d* in fig. 3) has become separated from the *true* rete Malpighii by the *new formation* of a median stratum lucidum (*c*).

That this is so can be proved in (α) an indirect and (β) direct manner.

α. It will not, I think, be admitted by any histologist that the horny scales which form the constituent elements of the stratum lucidum are capable of returning into polygonal granular nucleated cells just as little as those of the stratum corneum are capable of such a change. In the case of the primary pustules of sheep-pocks the cells of the *upper* rete Malpighii (*d* in fig. 3) are in those parts in which the hornification has not proceeded too far, of a distinctly granular substance and possess a well-defined nucleus, which stains with staining fluid, just like that of an ordinary epithelial cell; in short, they are in all respects identical with the cells of the *true* rete Malpighii. Double staining with carmine and hæmatoxylin shows one important difference between the two, viz. whereas the *true* rete Malpighii stains

of a light purple colour (hæmatoxylin), the *upper* rete Malpighii (*d* in fig. 3) assumes a pink colour (carmine), which is deeper in the cells next the strata lucida. As fig. 3 so beautifully shows, this deep pink colour is exhibited not only by cells of the *upper* rete Malpighii, but also by cells of the *true* rete Malpighii in the immediate vicinity of the median stratum lucidum, thus showing that those cells of the rete Malpighii which are here becoming converted into parts of the stratum lucidum lie not only in the *upper* rete Malpighii, but also in the superficial layer of the *true* rete Malpighii. [As I have described and figured in my paper in the 'Philosophical Transactions,' the median stratum lucidum possesses longer or shorter processes corresponding to the interpapillary processes of the true rete Malpighii; these are also well shown in the present fig. 3.]

Those cells of the rete Malpighii which are being converted into part of the stratum lucidum take especially well to carmine staining, as I have convinced myself also in preparations of early stages of the pock, *e. g.* in a stage represented in fig. 2. In this figure the layer *d* contains those cells; they still show their outlines, although indistinctly, but have lost their nuclei. But what is of paramount importance in this figure is the fact that the cells of the layer *d* have almost entirely lost their "granules." (In all these pathological cases the "granular layer," *i. e.* the layer of cells next the under surface of the stratum lucidum which contain larger or smaller "granules" staining very deeply blue in hæmatoxylin, and thus easily demonstrated, is much broader than in the normal condition. In the present case the layer *d* has no more distinct granules; they are to be found in the next lower layer *c*. Here they are very large spherical or disc-like masses, situated generally at and near the poles of the nucleus of the cell.) And this is in so far of interest, as it shows that the non-presence of granules in *d* of fig. 3 does not prove that this layer has never been part of the rete Malpighii; or expressed in a different way, the presence of granules in cells below the median stratum lucidum of fig. 3 does not at all prove that the *upper* rete (*d* of fig. 3) has always been part of the stratum lucidum.

But there is another reason why the *upper* rete Malpighii of our case (*d*, fig. 3) has not previously been part of the stratum lucidum, but, on the contrary, has become separated from the *deeper* rete Malpighii by the appearance of the median stratum lucidum. If we trace the changes of the epidermis from stage to stage we ascertain that the thickness of the (hypertrophied) rete Malpighii is at first greatest in

the central part of the pock, and, as I described in my paper ('Philosophical Transactions'), abruptly passes into the epidermis of the surrounding skin. But when the median horny streak (median stratum lucidum) has made its appearance in the centre of the pock—(as a rule it first appears in the centre of the pock, and gradually spreads from here towards the periphery, as I fully described in the 'Philosophical Transactions')—the rete Malpighii of the periphery, where there is no median horny streak, greatly exceeds in thickness the *deep* rete Malpighii of the centre; it exceeds in thickness even both the deep and upper rete Malpighii taken together. The explanation is not difficult to find; it is this: upper rete Malpighii, median horny streak *and* deep rete Malpighii (fig. 3) together once formed a uniform rete Malpighii in the centre of the pock; its thickness was then, of course, much greater than now, when by the hornification of some layers of cells (median horny streak) so much of its thickness has been lost.

β. The more direct proof that the *upper* rete Malpighii (*d*, fig. 3) has never been part of the original stratum lucidum is to be found in the fact that the median horny streak (median stratum lucidum) may be said to develop out of isolated horny masses of epithelial cells, which gradually become confluent, as I minutely described and figured in my paper in the 'Philosophical Transactions.'

The fact that "granular cells" (*b* of fig. 3) are found underneath the median horny streak does not prove that this latter is part of the original stratum lucidum—(in the normal epidermis the "granular cells" lie in close contact with the stratum lucidum, and one may be taken as index of the other)—for I have shown above (see fig. 2) that in our cases the position of the "granular cells" is not invariably a fixed one.

As I have pointed out in my paper in the 'Philosophical Transactions' the above condition, viz. appearance of a median horny streak is to be found in the primary pustules only, *i. e.* in those which appear directly at the seat of inoculation, and this condition does not precede the formation of the vesicles, as Dr. Unna maintains for the smallpox in man.

Dr. Unna attributes to the "Pockenkörper" a great importance, inasmuch as he regards it as the seat of the vesicles of the pustule in human smallpox. A comparison of his figures (l. c., Plate XV, figs. 3 and 4) with those which I obtained from secondary pustules of sheep-pocks—*i. e.* those that appeared like smallpox in man, in consequence of a

general eruption—show that in both cases the formation of the vesicles of the pustule takes place simply in the upper and middle cell-layers of the rete Malpighii. As regards the vesicles in the pustules of sheep-pox I have shown in my paper in the 'Philosophical Transactions' that hydropic degeneration and vacuolation of the cells of the rete Malpighii plays an important part in their formation. I can now add another fact, noteworthy in considering the modes of their formation. It is this: the intercellular paths (interstitial substance) become widely distended, and by the accumulation of fluid (contents of vesicles) gradually transformed in large irregular cavities, the surrounding epithelial cells at the same time becoming compressed and finally disappear. Fig. 1, which is a faithful representation of these relations, shows in *v* vesicles already formed; *i* are the intercellular paths, in some places widely distended; through them project the "spikes" of the ridge-and-furrow-cells. In the broad paths (fig. 1) we observe also a thin membranous structure (dark line), and it is not quite clear to me what this means. It possibly means this: during life these broad paths have been filled with a fluid, at any rate a liquefied intercellular substance, which, after death and by the action of the hardening reagent, coagulates; the coagulum appears in the form of a delicate membrane. At any rate the figure shows that some of the vesicles are derived from distended intercellular paths.

Dr. Unna's chief reason for maintaining that the vesicles of the pustule are formed in the "Pockenkörper" appears to be the position of the "granular layer." He finds, namely, that at the periphery the "granular layer" may be traced for a little distance underneath the part that contains the vesicles; at all events he does not find the "granular layer" extend above the vesicles. As regards the vesicles in the secondary pustules of sheep-pox—*i.e.* those of a general eruption—I find that there is a considerable difference between the periphery and the centre of the pustule. I have *invariably* found that in the early stages of the formation of the vesicles these latter are formed *underneath* the "granular layer." This is of so constant a character that no error is possible, and we must, therefore, set aside—at any rate for the pustules of sheep-pox of a general eruption—the assertion of Dr. Unna that the vesicles are formed above the "granular layer," *i.e.* within the stratum lucidum.

In the central part of the pustules of our cases the vesicles are formed in the middle and upper layers of the rete Malpighii, as I described and figured in my paper in the 'Phi-

losophical Transactions.' In the periphery, however, there we certainly meet with appearances which might suggest an interpretation such as is given by Dr. Unna, viz. there we find that the stratum lucidum appears to be separated into two layers, and between these lie the vesicles, generally of a considerable size, and separated only by thin trabecular remains of cell-masses. This condition—*i. e.* the presence of a median stratum lucidum *underneath* the vesicles—may be observed at first only at the very periphery; as development proceeds it extends also for some distance towards the central part of the pustule. In the very periphery we may find also an indication of a "granular layer" underneath the median stratum lucidum, traceable into the "granular layer" of the surrounding part. Now, all this seems to me to admit of an easy and simple interpretation, viz. that in the periphery the vesicles become first separated from the subjacent rete Malpighii by the hornification—or whatever that peculiar, highly-refractive, homogeneous condition may be—of the cell-layers of the rete Malpighii directly underneath the vesicles. I would particularly draw the attention to fig. 4, which represents a vertical section through the epidermis of a pustule of a general eruption. The right and middle of the drawing corresponds to the centre, the left to a part near the periphery of the pustule, and it is here seen that in the centre the vesicles lie *underneath* the "granular layer," *i. e.* in the *true* rete Malpighii; whereas in the periphery the superficial vesicles are already becoming separated from the rete Malpighii by a layer, which in its aspect corresponds to the median stratum lucidum. As is also shown in the drawing, it seems to branch off from the stratum lucidum of the surface. A section placed at a right angle to the plane of that represented in fig. 4 would, if placed through the peripheral part, show the vesicles enclosed between two strata lucida, the upper being the true stratum lucidum of the surface, the lower corresponding to the median horny streak (or median stratum lucidum); that is to say, we should find that the vesicles actually correspond in position to the "Pockenkörper," as maintained by Dr. Unna. But if that section were placed through the centre only, we should find no such thing; we should merely see the vesicles in the middle and upper layers of the true rete Malpighii *underneath* the "granular layer."

In an appendix to his paper Dr. Unna mentions that he learned by letter from Dr. Weigert, whose experience in the anatomy of smallpox of man is, I think, universally admitted to be of an authoritative character, that this observer

(Dr. Wiegert) regards Unna's "Pockenkörper" only as serving to separate the vesicles from the rete Malpighii, and thus to properly enclose them, "zur Abkapselung dient." In addition, Dr. Wiegert thinks that Dr. Unna's "Pockenkörper" is found only at the periphery of the pustule. I need hardly remind the reader that, according to our description above, I fully agree with Dr. Weigert's interpretation; and I would only mention that Auspitz and Basch (quoted by Dr. Neuman in his 'Textbook of Skin Diseases,' translated by Dr. Pullar, London, 1871, p. 74) knew the condition of human smallpox when "the pustular contents are enclosed, as if by a capsule, by two layers of unnucleated epidermic cells."

NOTES *on the* EMBRYOLOGY *and* CLASSIFICATION *of the* ANIMAL KINGDOM: *comprising a* REVISION *of* SPECULATIONS *relative to the* ORIGIN *and* SIGNIFICANCE *of the* GERM-LAYERS.

By E. RAY LANKESTER, M.A., F.R.S., Professor of Zoology and Comparative Anatomy in University College, London. With Plate XXV.

I.—THE PLANULA THEORY.

Preliminary.—The object of the present essay is to give, in a concise form, the actual phase which those speculations have assumed, which I first put forward in an article entitled, "On the Germinal Layers of the Embryo as the Basis of the Genealogical Classification of Animals," published in the 'Annals and Mag. of Nat. Hist.,' May, 1873. The points of chief importance in that article were the indication of three grades of developmental complexity in the animal kingdom—the homoblastic, limited to the Protozoa; the diploblastic, reaching no higher than the Zoophytes or Cœlentera; and the tripoblastic, embracing all the higher animals which differ from the Zoophytes built up by the modification of two primary cell-layers, in the fact that a third cell-layer appears between these two, and gives rise to muscles, body-cavity, and blood-vascular systems. The precise origin of this third germ-layer, as well as its exact relation to body-cavity and hæmolymph vessels, was pointed to as a matter requiring further observation and consideration. Further, in this article it was shown that both

the Diploblastica and Triploblastica, in the course of development from the egg, after passing through a "polyplast" condition, enter upon the Planula phase. The Planula was defined as a sac, the wall of which is composed of two layers of cells, an ectoderm and an endoderm. Such a Planula was presumed to be the common ancestor of all Diploblastica and Tripoblastica, the former of which retained its essential structure with small modifications, whilst the latter proceeded further to add the third layer and the hæmolymph system connected with it. The existence of an aperture leading into the cavity of the two-cell-layered Planula was not an essential feature of the ancestral form thus arrived at, for I was careful to insist, in the essay referred to, that the two-cell-layered Planula took its origin in the actual development of both Diploblastica and Triploblastica in two different ways, which I designated respectively "delamination" and "invagination." When the deeper or endodermal layer of cells arose by delamination from the inner face of a hollow polyplast, whose wall was formed by one primitive layer of cells, a closed two-cell-layered Planula was formed devoid of aperture, and subsequently a mouth was formed by a breaking through of the Planula's wall and an ingrowth of ectodermal cells. This mode of origin appeared to be confined to a few Zoophytes.

The invaginate mode of origin—in which a pushing in of the wall of a single-cell-layered sac gave rise to an internal cell-layer—appeared to be by far the commoner mode of origin of the two-cell-layered Planula, and in this case the cavity formed by the invagination and bounded by the invaginated endodermal cells is (for a time, at least) open to the exterior by the orifice of invagination. I pointed out in the essay, to which these remarks relate, that according to some observers this "orifice of invagination" persists as the mouth of the mature organism, whilst in other cases it closes up, and again in other cases becomes the anus. The difficult questions accordingly arose, Can the disruptive mouth of "delaminate Planulæ" be identical or homogenous[1] with the mouth persisting from the primary orifice of invagination? Is the latter kind of mouth identical or homogenous with the anal aperture of those organisms in which the orifice of invagination persists as anus? Must we regard the orifice of invagination as both mouth and anus, in fact as a "proctostom" or "oranus."

Professor Huxley, who in 1875 published some remarks on this subject ("On the Classification of the Animal

[1] Homogenous = derived from one and the same ancestral source. See "On the use of the term Homology," 'Annals and Mag. Nat. Hist.,' 1870.

Kingdom," 'Quart. Journ. Mic. Sci.,' January, 1875, and article "Animal Kingdom," 'Encyclopædia Britannica'), adopted the view, to which he still adheres ('Anatomy of Invertebrates,' Churchill, 1877), that we may distinguish among the higher animals the "archæostomatous" from the "deuterostomatous," the first category including those in which the orifice of invagination persists as the mouth, whilst the second category includes those in which the orifice of invagination either disappears or becomes the anus, whilst a secondary mouth is formed by disruption. A further consideration of the subject and new observations led me, about the same time, to the conclusion (see "On the Invaginate Planula of Paludina," 'Quart. Journ. Micr. Sci.,' April, 1875) that we have no ground for assuming that such a substitution of a secondary for a primitive mouth has taken place, since it is very possible (and, indeed, probable) that the orifice of invagination of invaginate Planulæ is in its origin not a mouth at all, but simply the necessary accompaniment of the invagination, destined *normally* to close up, as do other orifices of invagination (optic and auditory vesicles, vertebrate nerve-tube). Accordingly, I proposed to speak of the orifice of invagination, by means of which invaginate Planulæ acquire their endoderm, as simply the "blastopore," leaving thus the question of its relations to mouth and anus open for further inquiry. The view as to the historical relations of delaminate and invaginate Planulæ which I was thus led to adopt amounted to this: that, starting from the condition of a hollow polyplast, a vesicle bounded by a single layer of cells, the second condition, viz. that of a vesicle with a wall formed by two layers of cells, could be attained in two ways—1. More rarely by delamination. 2. More usually by invagination, the blastopore or orifice of invagination *closing up*, and thus rendering the two Planulæ identical in every respect. From this point of reunion the two Planulæ proceed on a common path, mouth and anus, or in Zoophytes mouth only, being formed by new growth and disruption.

This preliminary sketch is sufficient to enable me to make clear the distinction between what I might, for the sake of a name, call my "Planula theory," and Haeckel's "Gastrula" or "Gastræa theory." Haeckel's speculations were first sketched out in his 'Monograph of the Calcareous Sponges,' and were published shortly before the article in the 'Annals and Mag. Nat. Hist.' above mentioned, though the substance of this article had been previously given in my lectures, and was in no way influenced by the closely similar doctrine

enunciated by Haeckel. Since the whole of recent theory and inquiry as to the significance of the germ-layers of the embryo in relation to the pedigree of the animal kingdom is, in consequence of the interesting and vigorous writings of Professor Haeckel, commonly spoken of (in this country at least) as "Haeckel's Gastræa theory;" and since the distinctive points of a similar but independent theory are liable in consequence to be overlooked or misunderstood, I shall speak of the latter as the Planula theory, and point out what from the first has been the fundamental difference (coexisting with a fundamental agreement) between Hæckel's Gastræa theory and the Planula theory.

Objections to Haeckel's views.—The developmental and historic form which Haeckel's theory assumes, and to which he gives the name Gastrula or Gastræa, is similar to my diploblastic Planula, with this exception, that it has a mouth. Haeckel definitely regards the orifice of invagination or blastopore as the "Urmund," or primitive mouth, and in his most recent writings has unreservedly committed himself to the proposition that the ancestral Gastræa originated by invagination, that the orifice of invagination is the creature's mouth, and that those recorded cases in which the embryonic two-cell-layered sac is stated to arise by delamination are, like his own statements relative to the delaminate origin of the endoderm in calcareous sponges, cases in which observers have erroneously overlooked the invagination process. In my article of May, 1873, I had in view the possibility of an identity between blastopore and primitive mouth, and, indeed, supposed that the Zoophytes might be distinguished from higher organisms by the fact that they possessed the primitive, as distinguished from a secondary mouth. On the other hand, I have since seen reason to abandon altogether the notion that the blastopore represents a mouth, and differ from Professors Haeckel and Huxley on this point.

I further disagree with them as to the universality of the origin of the diploblastic phase by invagination. I hold that we have at least one *apparently* well-observed case of the formation of an endoderm by delamination ('Fol, Die erste Entwickelung des Geryonidencies Jenaische Zeitschr.,' vol. vii, p. 471), and, further, that even without such evidence (which ought to be re-examined) it is possible to give a more satisfactory explanation of the early phenomena of animal development on the hypothesis that *the endoderm originated primitively by delamination*, which has been superseded by invagination through the operation of readily con-

ceivable mechanical causes, than it is to marshal the same series of facts in accordance with Haeckel's doctrine of the invaginate mouth-bearing Gastræa.

The historic series according to the Planula theory.—Accordingly, I shall briefly pass in review what I conceive to have been the course of historical development, pointing out how these historical phases reappear in more or less modified forms in the embryonic histories of to-day.

1. THE MONOPLAST = OVUM.—The unicellular ancestors of the higher animals are represented by the unicellular ovum. Just as we find existent unicellular animals exhibiting differentiation into ectoplasm and endoplasm, so do we find ectoplasm and endoplasm differentiated in many eggs. The differentiation of anterior and posterior regions, which is more rarely seen in living Protozoa, is the rule in the mono-

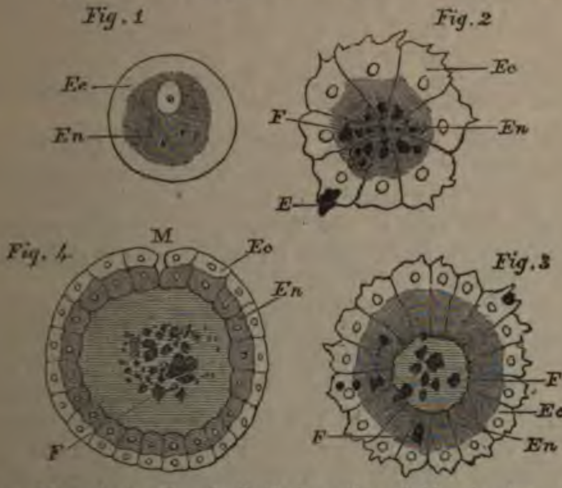


FIG. 1. Monoplast. FIG. 2. Optical section of Morula stage. FIG. 3. Optical section of Diblastula. FIG. 5. Section of Diblastula, with mouth. *Ec*, Ectoderm. *En*, Endoderm. *M*, Mouth. *F*, Food particles.

plastic phase of individual development. Just as unicellular animals contain granular matter, which as metaplasm is distinguished from the hyaline protoplasm in which such granules float, so in the egg-cell we find a greater or less amount of granular matter, which it is convenient to speak of as food-material. As in the unicellular organism some of the granular matter present, is the result of chemical activity in the protoplasm—that is to say, is the product of assimilation and subsequent segregation, whilst other (usually coarser) particles are *particles of* food which have been incepted, but

not yet assimilated—so in the corresponding phase of individual development we find the food material consisting of two kinds of granular matter, one of which has been taken in by the egg-cell from its parent organism, *assimilated* and deposited as the result of a chemical segregation, the other, which is often of enormous relative bulk, consisting of coarse granules or masses which have been *engulphed* by the protoplasm of the egg during its sojourn in the maternal ovary or ducts. Such coarse and bulky food material is prepared for the young egg-cell by neighbouring cells of the maternal organism, and may very fitly be compared, after it has been incepted by the ovum, to the organic masses with which a naked Protozoon gorges itself for purposes of nutrition.[1]

The amount and the disposition of the food material in the ovum varies very greatly in different organisms. Its variation is the direct cause of differences in the arrangement and size of the cells into which the egg-cell divides, and becomes thus the obvious source of discrepancy between the inferred ancestral (phylogenetic) and actual (ontogenetic) developmental phases.

The ancestral monoplast must have been free from any large quantity of granular matter, whether segregated or incepted, but we may assume its mode of taking food to have been similar to that of the Amœba, and that in response to incidental and intrinsic forces its substance was differentiated into an ectoplasm and an endoplasm.

2. THE POLYPLAST=MULBERRY PHASE OR MORULA (Haeckel). —In the course of the historic development of animals, the monoplast gave rise by division to spherical colonies consisting of many adherent cells. These, we assume, continued to nourish themselves by the inception of solid particles at their free surface. The process which development appears to have taken requires us to distinguish two conditions of the Polyplast: *a*, an earlier one (Fig. 2), in which the constitutional cells were closely adherent so as to form a solid sphere, distinguished by Haeckel as the morula; *b*, a later (Fig. 3), in which the accumulation of liquid at the centre of the sphere built up by the cells gradually resulted in the formation of a considerable cavity (the blastocœl, Huxley), so that the polyplast now acquired the form of a vesicle, its wall formed by a single series of equi-formal cells and its cavity filled up by a liquid which had traversed the substance of these cells. This hollow polyplast has been designated by Haeckel the blastula. We must assume that food was still incepted

[1] See my observations on the ovarian egg of Loligo, in the 'Phil. Trans.,' 1875.

by the naked surface of all the constituent cells. At the same time nothing could be more probable than that the outer and the inner portions of each cell should acquire different structure and properties, such as may, at this day, be seen to be acquired by the cells forming the wall of the blastula-phase of the jelly-fish, Geryonia (Figs. 5, 6). The liquid within the cavity of the blastula was probably enough of a special nature, and together with secreted products from the cells, undigested food particles may have passed through the substance of the cells into this blastocœl, and there have been dissolved, so that an incipient digestive function was acquired by the blastocœl.

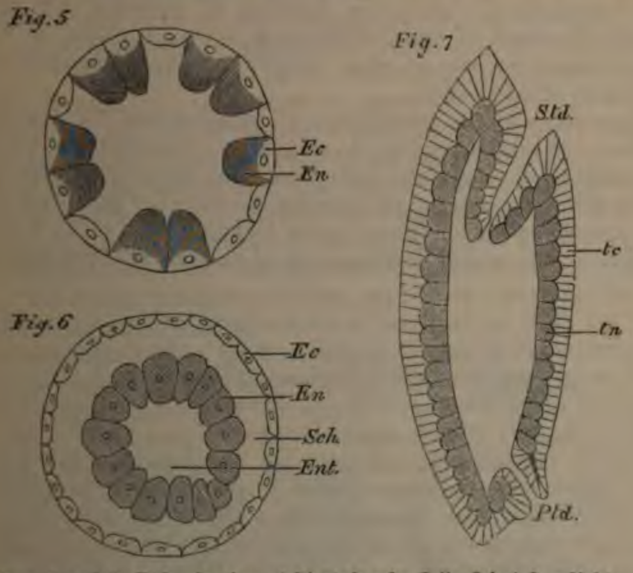
3. THE DIPLOBLASTIC PLANULA = DIBLASTULA (Salensky).—The differentiation set up between the inner and the outer portions of the cells forming in a single layer the wall of the blastula now (we infer) advanced so far that each cell divided into two, an inner cell and an outer cell. Possibly, not all the cells composing the wall of the blastula took part in this process. The result was the formation of an endoderm or enteric cell-layer by delamination. The cavity now enclosed by its special layer of cells is conveniently termed the ENTERON OF ARCHENTERON (Urdurm); the cell-layer is accordingly the enteric cell-layer; on the other hand, the outer set of cells usually known according to the terminology introduced by Professor Allman in treating of the Hydroid polyps as ectoderm, may also conveniently be termed the DERON or deric cell-layer. The delaminate Planula or Diblastula (a term which I adopt from Professor Salensky) continued to nourish itself by the inception of solid food by the naked protoplasm of its ectodermic cells. We must, however, suppose that as the differentiation of the deric and enteric cell-layers advanced, the inception of nutriment became limited to one spot on the deric surface, and that at this spot solid particles of food were passed through the soft protoplasm into the enteron there, to be digested. The development of cilia on the general surface, and of locomotion, would account for this localisation. A rupture of the sac at this point and the establishment of an open way into the already actively secreting and absorbing digestive cavity, would constitute the mouth.

Whatever view we take as to the original mode of formation of the digestive cavity or enteron, the difficulty has to be encountered of forming a conception of the steps by which the two vastly different modes of digestion which we meet with in the animal series could pass one into the other. The *physiology of alimentation* in a Protozoon, such as an Amœba

or an Infusorian, on the one hand, and of even the simplest of the Enterozoa (the animals with an enteron or gut), differs in the most important manner and to an extent which is hardly sufficiently recognised. Whilst in the Protozoon the raw, unprepared particle of solid food is plunged into the living protoplasm of the cell, and, lying within a temporary cavity partly filled with water, is digested within the protoplasm, no such inception of solid particles by the cells of the enteron takes place, except perhaps in the sponges. In the Enterozoa the food, though, as in all nonparasitic animals, it is seized in the solid state, is yet not introduced into the cell protoplasm in that state. It is dissolved in the enteron by the action of secretions there accumulated, and passes only by diffusion into the protoplasm of the enteric cells. The whole significance of the enteric cavity—the physiological motive of its differentiation—appears to be that of a laboratory retort. The hypothesis of its primitive appearance as a closed cavity into which solid food particles were passed *through* the protoplasm of the cells as into a food-vacuole common to the cell colony, is in harmony with this assumed physiological motive. On the other hand, it does not seem possible to reconcile the physiological significance of the enteron with the hypothesis that it took its rise in a gradually deepening depression of the surface of a spherical blastula—that is to say, by invagination. Such an area of depression is assumed by the invagination-hypothesis to have become the exclusively nutritive area. Its cells must be actively taking in solid particles of food at the surface like so many Amœbæ. What motive is there on such an assumption for the deepening of the depression? In what way can we suppose that the amœboid cells of this area came to cease the habit of seizing and ingesting solid particles, and took to the outpouring of digestive juices and the passive function of absorption? By what influences are we to suppose that the depression was sufficiently deepened and its margin sufficiently narrowed to retain a digestive fluid? The answer to these questions appears to me to involve more difficulty than we encounter in tracing out the hypothesis of the origin of the enteric cell-layer by delamination. This preliminary advantage of the latter hypothesis is, we shall see, independently strengthened and fortified by the facts and arguments with which we meet at later stages.

4. *Formation of the* STOMODÆUM *and* PROCTODÆUM.—The breaking through of the mouth of the Diblastula, in the form of a definite aperture, appears to have assumed neither

an "eruptive" nor a "disruptive" character, but to have been rather "inruptive"—that is to say, the establishment of the mouth as a permanent structure was accompanied by an *ingrowth* of ectodermal cells, no doubt very slight at first, but afterwards attaining great size and importance as the first portion of the alimentary tract. It is this ingrowth which gives rise to what is often called "pharynx" in Mollusca, Arthropoda, and Vermes. I have proposed[1] to designate this ingrowth of the deron, the STOMODÆUM (*στομοδαιον*, like *πυλοδαιον*, the road connected with a gateway), and similarly to call another ingrowth which accompanies the formation of the second orifice (the anus) of the enteron, the PROCTODÆUM. The mouth and stomodæum



FIGS. 5 and 6. Delamination of Blastula of a Jelly-fish (after Fol.).
Ec, Ectoderm. *En*, Entoderm (Enteron). *Sch*, Schizocœl.
FIG. 7. *tc.*, deron; *tn.*, enteron; *Std.*, stomodæum; *Ptd.*, proctodæum.

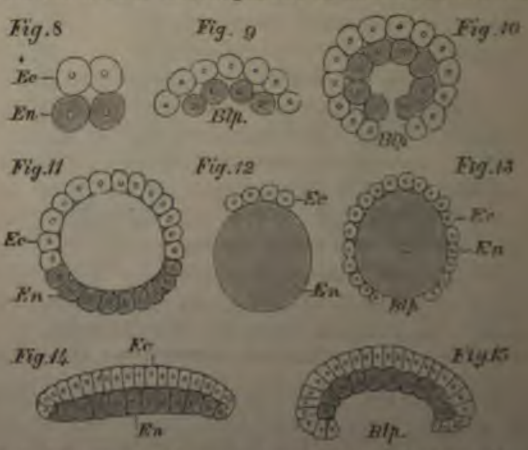
appear to have existed some time before an anal orifice was developed, and the mouth must have functioned as it does in living Zoophytes, both for the ingress of food to the enteron and the rejection of undigested remnants. The development of an anus and proctodæum may be conceived of as due to the gradual establishment of an, at first, purely mechanical rupture, as a permanent hereditary feature. In the recapitu-

[1] 'Quart. Journ. Mic. Sci.,' April, 1876.

lative ontogeny of a large number of organisms living at this day it forms by rupture.

Leaving now for the moment the task of further detailing the hypothetical changes which the ancestors of the Enterozoa underwent (to which we shall return), let us, having thus pictured to ourselves the steps by which a hollow cell-multiple, derived from a single cell, gave rise to an enteric cell-layer by delamination, and acquired a mouth with stomodæum and an anus with proctodæum—whilst various changes of general form were affected and sundry tentacular and such-like organs probably developed—inquire how the observed facts of the early stages of individual development in animals can be explained by applying to these facts and to our hypothetical sketch the doctrine of heredity, viz. that the development of the individual is a recapitulation of the development of the species, interrupted and modified by processes of adaptation.

Hypothesis of the substitution of Invagination for Delamination.—Whilst according to the above hypothetical sketch of ancestral development from the monoplast to the diblastula—the primitive enteron or digestive cavity is the blastocœl and the enteric cell layer forms by the Delamination of its wall—we find in the actual development of animals that the process



FIGS. 8, 9, 10. Stages of egg-division and invagination without formation of a pseudoblastula. FIG. 11. Pseudoblastula. FIG. 12, 13. Epibolic invagination. FIGS. 14, 15. Invagination as seen in Earthworm and Nematoda. *Ec.* Deron; *En.* Enteron; *Blp.* Blastopore.

of Invagination in one modification or another, is almost universal. Indeed, Professor Haeckel and Professor Huxley are inclined to think that it is universal. We have, how

ever, the observations already cited concerning the Geryonidæ and some observations of Kowalewsky on Alcyonium, and on species of Actiniæ, which indicate the development of an enteric cell-layer by Delamination. In the development of the enteron by Invagination, usually a number of cells become depressed in a cup-like manner on the surface of the blastula, sinking more and more deeply into the blastocœl (if such cavity be present), until the once spherical blastula (Fig. 11) has become a hemispherical cup, built up of two cell-layers, one pressed against the other (Fig. 15). The rim of the cup now contracts, and frequently closes; the wider or narrower orifice thus formed I have termed the *blastopore*. The case just described is that of an organism in which the egg-cell contains relatively a small amount of food-material, and when consequently the cells of the morula and of the blastula are of nearly equal size. Haeckel has called this the Archiblastic type. When there is more food-material in the egg, it either collects to the centre of the mass of cells as division proceeds, and segregates in a way which strongly suggests delamination,[1] lying eventually in the central cavity of a vesicle (blastula), formed by a single layer of cells (Periblastic type, Haeckel), *or* the food-material is associated from the first post-seminate phases of the egg-cell with one hemisphere or larger moiety of the egg, namely, that which is destined to form the enteric cell-layer, whilst the part of the egg (often extremely small) which is destined to form the deron or ectoderm is free (or becomes so by segregation) from such food-material. The consequence of this arrangement is that the enteric moiety of the egg-cell is separated in the earlier phases of cleavage from the deric moiety (Fig. 12), and is not only more bulky, but breaks up into new cells more slowly than the latter, so that it becomes overgrown by the deric cells rather than invaginated into them (Fig. 13). Two degrees of this Epibolic mode of Invagination (so called by Selenka, in distinction from the Embolic mode) are distinguished by Haeckel as Amphiblastic and Discoblastic.

It is clear enough that the special modifications of the process of invagination due to the presence in the egg of a large amount of food-material may be dismissed in considering the question as to how the process of Delamination came to be replaced by that of Invagination, since the presence of such an excess of food-material is a secondary and late condition. The facts, however, connected with the behaviour of the food-material, when present, suggest the explanation

[1] The formation of the enteron in periblastic forms such as the Arthropoda and Anthozoa (*Alcyonium*) requires much further study.

of the connection between Delamination and Invagination. All differentiation of cells, the development of one kind of cell from another kind, is dependent on internal movements of the physiological molecules of the protoplasm of such cells. When Delamination occurs in the cells of the blastula of Geryonia, or when it occurred in the ancestral blastula, the molecules destined to build up the enteric cell and deric cell, into which one of the primitive cells divides, are already present before they are made visible to the eye by segregation and accumulation on opposite faces of the differentiating cell. Though the substance of a cell may appear homogeneous under the most powerful microscope, excepting for the fine granular matter suspended in it, it is quite possible, indeed certain, that it may contain, *already formed and individualised,* various kinds of physiological molecules. The visible process of segregation is only the sequel of a differentiation already established, and not visible. The descendants of the Diblastula (diploblastic Planula), which had gradually acquired a separate deric and enteric cell-layer in place of one cell-layer with an external deric moiety and an internal enteric moiety to each cell, must have tended in their individual development from the egg-cells of parent Diblastulæ to have established more and more early, in the course of their growth, the important separation of deric and enteric cells, of ectodermic and endodermic elements. In so far as the differentiation of the two kinds of factors or molecules, the deric and the enteric, became dependent on heredity, and less dependent on the direct adaptative causes which first brought about the differentiation, in so far would it be possible for the differentiation, the segregation of deric molecules from enteric molecules, to take place at an earlier point in the embryonic development than that (namely, the blastula stage), at which the direct adaptative causes could come into operation. Thus, since the fertilised egg already contained hereditarily acquired molecules, both deric and enteric, invisible though differentiated, there would be a possibility that these two kinds of molecules should part company, *not* after the egg-cell had broken up into many cells as a morula, but at the very first step in the multiplication of the egg-cell. In fact, some or all of the deric molecules might remain in one of the two first cleavage-cells, and all of the enteric molecules, with or without some of the deric molecules, might remain in the other. We should not be able to recognise these molecules by sight; the two cleavage-cells would present an identical appearance, and yet the segregation of deric and enteric factors had already taken place. This

hypothesis may be called that of PRECOCIOUS SEGREGATION: "precocious," since it is the acquirement of a condition in the developing organism, in virtue of heredity, at an earlier period of development than that at which such acquirement was attained by its forefathers through adaptation. The tendency to precocity in this sense, in regard to important structural arrangements, has been insisted on by Haeckel in discussing what he terms "heterochrony in the palingenetic phenomena of ontogeny;" and the existence of such precocity is as well established as any part of the speculative edifice with which we are dealing, both on *à priori* and *à posteriori* grounds.

Having, then, arrived at this point, viz. the separation of deric and enteric elements in the first two cells of the developing organism, as a naturally conceivable sequence to the primary process of the separation of these elements by delamination of the walls of a many-celled blastula, let us pursue the case further.

How, it may be asked, are we to suppose that the enteric and deric cell thus early differentiated should have acquired the faculty of dividing in such a manner that the offspring of the enteric cell form a vesicle which, as it forms, becomes sunk within another vesicle constituted by the deric cells, and that thus the result is a diploblastic Planula or Diblastula identical with that formed by Delamination?

It might be urged that the result of further division on the part of the two primary cells could only be the formation of a vesicular one-cell-layered sac, of the same morphological character as the blastula which precedes the delaminate diblastula, and that we have no suggestion on our present hypothesis of any motive for the invagination of one hemisphere of the blastula so developed within the other. We have, however, first of all to note that the blastula (the one-cell-layered sac) belonging to the invaginate series is never precisely the homologue of the blastula belonging to the delaminate series, inasmuch as, according to our hypothesis (and as a matter of actual observation in all invaginate developments), the cells of the blastula belonging to an invaginate development are not equivalent one to another, as they are in the blastula of a delaminate development. In an invaginate development from the first the offspring of the primary enteric cell are to be distinguished[1] from the offspring of the deric cell, though to the eye there may be no structural distinction (Fig. 8). Accordingly, the blastula of an invaginate development has one hemisphere, or a certain area composed of enteric cells, whilst the rest are deric (Fig. 11).

[1] *By means of the 'directive corpuscles.'*

Now, we must remember that, however difficult it may be to form a mechanical conception of the processes by which the cells derived by division from an enbryonic cell take up certain definite positions, so as to form definite organs comparable to those of the parent organisms (thus exhibiting what we call heredity), it is no more difficult to form a mechanical con, ception of this power of self-arrangement and co-ordination as it exhibits itself after a certain amount of interference with the routine of recapitulative heredity, than as it exhibits itself when that routine is uninterruptedly pursued. In virtue of an hereditarily transmitted molecular structure the cells formed by division of the egg-cell in a delaminate development arrange themselves as a sac, the blastula. In virtue of hereditarily transmitted molecular structure the offspring of the enteric and the offspring of the deric cells, which are differentiated in the first cleavage of the egg of an invaginate development, arrange themselves as two vesicles, the latter within the former, the two groups of cells, each reproducing from the first, the characters of the endoderm and ectoderm of the parental Diblastula, in regard to such points as plane of cleavage, contact of the cells of one layer with one another, and contact with those of the other layer. Accordingly, the immediate apposition of the endodermal to the ectodermal cells (such as often occurs, *e.g.* in mammals, in nematods, and in the earthworm), without the formation of a vesicular blastula, is what we should look for (Figs. 9, 14).

The formation of a vesicular blastula in the course of an invaginate development is a secondary process: such a blastula (Fig. 11) is *not* the representative of the ancestral blastula (Fig. 3) which appears in the course of the delaminate development; it is due to mechanical non-hereditary accumulation of liquid among the primary cells of the embryo, and distorts the recapitulative development. The blastula of the invaginate development may be called a 'pseudoblastula' to distinguish it from the ancestral blastula. Haeckel's archiblastula is a pseudoblastula, and its cavity *does not correspond with the cavity of the delaminate blastula*, which immediately becomes the archenteron. We distinguish the archenteric blastocœl from the pseudoblastocœl.

The space which is formed within or is enclosed by the products of the enteric primary cell is, of course, the homologue of the blastocœl of delaminate development. It is this which becomes the archenteron. As the multiplication of the deric and enteric cells goes on, the cavity enclosed by the enteric cells becomes more distinct. The margin of the

incomplete double vesicle tends to bend inward (Fig. 9), and to complete the vesicle by closing up (Fig. 10), and it is necessary to assume that in the early history of invagination it did quite close. In the primary phase of invaginate development the blastopore was obliterated in due course as cell division went on. The persistence of the blastopore and the establishment of a relation sometimes between it and the mouth by means of of the stomodæum, and sometimes between it and the anus by means of the proctodæum were later adaptations.

5. *Coincidence of the blastopore with the mouth and with the anus.*—On examining the actual developmental histories of Enterozoa which have up to the present time been recorded by means of careful observation we find that by far the majority exhibit the formation of a Diblastula by invagination, the invaginated enteron in many cases consisting of but a few large cells, or even at first of only one large cell. The blastopore closes up in many cases; it does so in the molluscs Pisidium and Unio, in many Gastropods and Vermes, in Cephalopods, and in Vertebrata. Subsequently, as has been above described for the hypothetical ancestral form, a mouth and an anus eat their way into the completely closed Diblastula by means, respectively, of a stomodæum and of a proctodæum, or of a stomodæal aud a proctodæal invagination.

On the other hand, there are numerous cases in which the blastopore does not close up, but appears to persist as mouth in one set of cases, as anus in another set of cases. Regarding, as I do, the blastopore as an orifice of a secondary nature existing solely in relation to the invagination process, and originating after mouth and anus had made their appearance in the progress of animal evolution, I seek to explain its occasional relation to the mouth and to the anus as cases of adaptation. A parallel case of the adaptation of an orifice of invagination to functional purposes will be useful for my argument. The primary optic vesicle, like the nerve ganglion-masses, was originally developed by delamination in higher animals, but has in many cases taken to a development by invagination. In the Cephalopods the vesicle presents at an early stage a wide rim or margin, which gradually closes in leaving for a time a small orifice comparable to the blastopore of an invaginate diblastula. This orifice is obliterated in the Dibranchiate Cephalopods, but in Nautilus it is seized upon by adaptation and made use of as the chief optical condition of the whole ophthalmic apparatus. It serves in place of a lens or refractive body, to produce an image on the retinal surface in virtue of its pin-

hole character. Here we have a secondary accidental accompaniment of the invagination process—namely, the necessary orifice of invagination, rising suddenly to the importance of a substitute for refracting media which were differentiated in the tissues of the eye, before invagination had supplanted delamination in its development. Just as the orifice of invagination in the Cephalopod's eye is made use of in certain Cephalopods, but not in all, so is the blastopore made use of in certain invaginate Diblastulæ, but not in all, and not in all in the same way.

In certain Prosobranchiate Gastropods, most carefully studied by Bobretzky, the stomodæum, the deric (ectodermic) ingrowth belonging to the mouth, occurs either at the spot where the blastopore has just closed, or *before it has closed*, so that the oral ingrowth forms *around the blastopore;* and thus the blastopore does not close, though it is inaccurate to to say that it *becomes* the mouth. The same process takes place, in all probability, according to Kowalewsky's observations, in the earthworm and in some zoophytes; also in nematoid worms, according to Bütschli. These are the cases which have led to the supposition that the blastopore is the primitive mouth of Enterozoa, and these particular forms are those which have been called archæostomatous. But it will be observed that in these cases the normal mode of the formation of the mouth is not departed from; a stomodæum, an ingrowth of ectodermal cells, takes place here as in the ancestral delaminate type, which we have sketched above. The mouth and stomodæum merely avail themselves, as it were, of the blastopore soon about to close, and so a coincidence is effected.

In other cases—the Echinoderms, Paludina, among Prosobranch Gastropods, and probably many other animals—it is the anus, with its proctodæal ingrowth, which adapts itself to the blastopore. In the Pulmonate Limnæus both anal and oral growths develop on the site of the elongated blastopore. By regarding all these cases as late and special adaptations of the blastopore—itself a secondary structure concerned in the mechanism of egg-cleavage, and not developed with a specific function—we are able to explain, in a measure, the very astounding fact that what becomes the mouth of a whelk appears to become the anus of a water-snail. A very slight mechanical variation of conditions may be conceded to be sufficient to cause a small shifting in the position of the unsignificant orifice of invagination, so as to bring it within the predestined area of either stomodæum or proctodæum.

Comparison of the applicability of the hypothesis of a primary

delamination, and of the hypothesis of a primary invagination. We shall now briefly state the difficulties which are encountered by Haeckel's Gastræa theory in reference to the earlier stages of development, and point out to what extent these difficulties are avoided by the Planula theory.

If we assume with Haeckel that the process of invagination represents the historical mode of the formation of the enteron, and that the blastopore is the primitive mouth, we meet with difficulty as to (1) the transition from the inceptive nutrition of amœboid cells to the absorptive nutrition of the cells lining a more or less completely enclosed digestive chamber; (2) the substitution, by a process of retardation, of delamination in a few rare cases for the supposed more archaic invagination; (3) the disappearance, in some cases, of the supposed primitive mouth, and the formation of a new secondary mouth, whilst in closely allied forms the supposed primitive mouth persists as mouth, or again ceases to be mouth and becomes anus, whilst a new mouth develops; the result being that the mouth of one Gastropod (to take an example) has to be considered as the homologue of the anus of another.

On the other hand, the hypothesis of primary delamination and secondary invagination gives an intelligible scheme of the development of an enteron by the formation of a cavity at the central meeting-point of a colony of amœboid cells, and the subsequent differentiation of two cell-layers already foreshadowed in the differentiation of the outer and inner portion of each cell. The hypothesis of precocious segregation explains the common replacement of the original process of delamination by invagination, and accounts for the blastopore. The blastopore being thus explained, we have no further assumptions to make as to primary and secondary mouths, and we avoid the fatal objection which can be urged against Haeckel's theory—that it admits of a *reductio ad absurdum,* since, in reasoning from it, we are driven to the conclusion that the mouth of a whelk is the homologue of the anus of a water-snail.

II. FORMATION OF THE MESODERM AND BODY-CAVITY (CŒLOM).

So far I have only discussed the origin of the two primitive cell-layers and the primitive dominant organ of the animal economy—the enteron. External changes of shape and prolongations of cells (cilia) or groups of cells (tentacles), as locomotor and prehensile organs, have not been touched upon. These I shall allude to in due course, but first of all must deal with *important* changes which supervene in regard

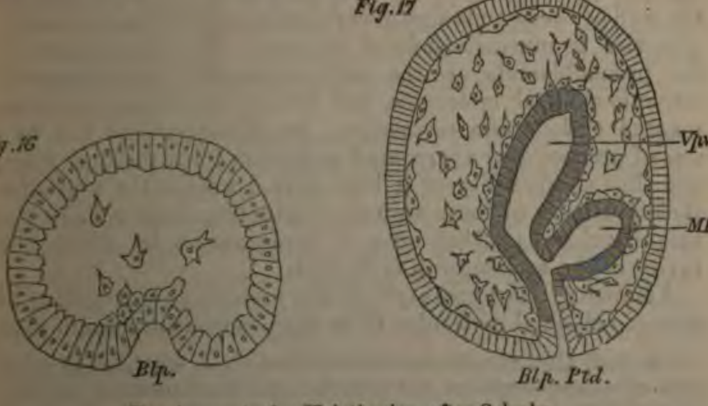
maintained, and does, I believe, to this day, that the cœlom originated ancestrally by splitting between the deron with its hypoderic cell-layers, and the enteron with its hypenteric cell-layers, and that it had nothing to do with "gastro-vascular outgrowths." In my paper on the "Invaginate Planula of Paludina," just referred to, I gave the first explanation of the cœlom as uniformly derived from the enteron, and traceable to "gastro-vascular" cavities. This view is entertained by Professor Huxley ('The Anatomy of Invertebrated Animals,' p. 686), though he makes reservations in favour of a schizocœlous condition for Rotifera and Polyzoa. It appears to me to be unnecessary to admit a schizocœlous origin of the cœlom in any case. It is uniformly developed from parenteric growths, and under extreme modifications the essential features of its ancestral relations can be traced in the most exceptional cases. Thus there are not a few developmental histories in which, as a purely embryonic phenomenon, liquid accumulates between the invaginated enteron and the vesicular deron or ectoderm. This cavity is really only a developmental feature, part of the non-historic mechanism of growth, like the blastopore, and is a continuation of the pseudo-blastocœl. Enteric cells grow out in two little parenteric masses from the enteron, and then separate widely from one another, spread out, become amœbiform, crawl all over the inner wall of the ectodermic vesicle and line it throughout (see my "Observations on Pisidium," 'Phil. Trans.,' 1875). They thus spread themselves out and *enclose* a large space; they form ultimately the lining cells of the cœlom, so that even where only a few branched cells appear between deron and enteron, they may carry out the essential features of development of the cœlom from parenteric diverticula.

According to the hypothesis just set forth, we must look, then, in *all* animals with a cœlom, that is to say, in all the higher animals, for parenteric growths, lateral masses of cells of the endoderm, the progeny of which can be traced in further development to *the epithelium* (the lining cell-membrane), *of all and any sanguiferous or lymphatic cavities or canals, and to the corpuscles floating in such cavities.*

The facts observed in the development of higher animals admit very well of this interpretation, only there is this difficulty, that in many cases parenteric growths appear to give rise *to a good deal more* than the cœlom and its epithelium. In fact, in Vertebrata the whole of the muscular and skeletal tissues as well, instead of being delaminated from ectoderm, appear to originate, together with the cœlomic

parentera, from masses of cells separating from the primitive enteron. In the Vertebrates it is most clear that only a small axial tract, if any, of the cells which give rise to muscular-skeletal tissues originates from ectoderm. The original mode of formation by delamination has been lost. The parenteric growths, separating early whilst all the cells of the embryo are neutral in appearance, form a large intermediate sheet of cells—the much debated "mesoblast" or "mesoderm"—and from this layer, muscular and skeletal cells, vascular and cœlomic epithelium, all alike develop. Compare with this extreme state of modification the more ancestral mode of development of the corresponding parts of the tissues of Holothurians, as described in the valuable and important memoir of Selenka ('Zeitsch. Wiss. Zool.,' vol. xxvi). In Holothuria, the two elements which in the Vertebrates are confused to the eye, and which are too often mentally confused under the one name of mesoblast, are seen taking their distinct origins, not, I believe, the quite ancestral origin, but presenting a most suggestive departure from that ancestral phase. To agree with the ancestor, as in Zoophytes, the cells of the embryo Holothurian, which are to give rise to muscles and skeletal tissue, should originate from the whole internal surface of the ectoderm or deron by delamination, but instead of doing

Fig. 16 Fig. 17



Development of a Holothurian, after Selenka.
Blp. Blastopore; *Ptd.* Proctodæum; *Vpv.* Vasoperitoneal or cœlomic vesicle, the Parenteron. *M.E.* Digestive Sac or Metenteron.

this, they *either* proceed from the multiplication of a few cells, separated at a very early period at the inner face of the pole of invagination, or they originate a little later from that

same point (fig. 16). In any case they maintain a complete independence of the cœlomic "parentera," and only apply themselves at a later period to these outgrowths, in order to form the musculature of the walls of the canals and cavities to which the archenteron gives rise (fig. 17).

The condition of things in reference to the origin of the musculo-skeletal cells seen in the Holothurians may be explained as a derivative of the delamination process seen in the formation of the identical tissues of Zoophytes, by the application of the hypothesis of precocious segregation. Just as the delaminate origin of the endoderm gives place to an invaginate origin, owing to the early segregation of the two elements, so the ectodermic cells at this later stage of evolution cease to develop the musculo-skeletal cells by delamination, and at a time when the embryo is composed of only twelve, eight, or even two cells, the molecules possessing by heredity the power of giving rise to musculo-skeletal tissues are segregated from the cells destined to form ectoderm pure and simple, which now, indeed, having lost its musculo-skeletal elements, should be distinguished from the primitive ectoderm, as epiblast.[1] This segregation taking place before the pseudoblastula is formed (in rare cases of retention of the ancestral delaminate origin of the enteric cells, the musculo-skeletal tissue also originates by delamination) we find that the greater portion of the cells forming the wall of the pseudoblastula are purely epiblastic, and never give rise to musculo-skeletal progeny. But at one part of the pseudoblastula are the cells containing the segregated musculo-skeletal molecules, and others containing the segregated endodermic molecules. In Holothurians the two sets of precociously segregated molecules form distinct cells, and thus at an earlier or a later period we see the musculo-skeletal tissues of these animals originating from cells in the neighbourhood of that area of invagination by which the cavity of the archenteron is formed.

Admitting this hypothesis of the precocious segregation of musculo-skeletal molecules to be true, it is clear enough that

[1] As Prof. Allen Thomson has recently pointed out, ectoderm and endoderm correspond to epiblast and hypoblast, plus the share which ectoderm and endoderm have in the mesoblast (Brit. Ass., Plymouth, President's Address, 1877). In fact, we arrive now by the light of minute investigations of Invertebrate ontogeny at a striking confirmation of the views of von Baer. The primary cells of the embryo differentiate into two layers, the ectoderm and the endoderm, or deron and enteron. Each of these again divides into two: the ectoderm into epiblast and musculo-skeletal tissue, the endoderm into hypoblast and cœlomic epithelium (parenteric outgrowths).

we *may* have many varieties as to the exact time and mode of such segregation; and thus, I think, we may explain the various modes of origin which careful observers ascribe to the musculo-skeletal tissues in various cases. To return, for example, to the case of the Vertebrates: it appears that the whole, or very nearly the whole, of the musculo-skeletal tissues in those animals are the progeny of the endodermic cells, that is to say, develop from the parenteric outgrowths. Our hypothesis of precocious segregation explains this, for we have only to suppose that, during the first cell-division of the egg-cell, the precociously segregated musculo-skeletal molecules do not form distinct isolated cells, *but accompany the endodermic cells*, and do not segregate from these latter until they have formed the parenteric cell-masses. Thus the parenteric cell-masses of Vertebrata, whilst they represent the gastro-vascular diverticula of the Cœlenterate-phase of animal evolution, contain at the same time the hereditary musculo-skeletal molecules. Hence the mesoblast of Vertebrates represents *in form* the cœlomic diverticula, whilst *in substance* it also is the representative of the musculo-skeletal tissue, primarily differentiated by delamination of an ectoderm. In this way we are able to explain—that is, to form a plausible conception of the mechanism of—two very puzzling embryological phenomena, *by means of one hypothesis*. The phenomena are the formation of an enteron, sometimes by Delamination, sometimes by Invagination with a blastopore, and the formation of the musculo-skeletal tissues, sometimes by delamination from the ectoderm, sometimes by outgrowth of the enteron.

Among the many variations possible in the origin of mesoblast—musculo-skeletal tissue *plus* cœlomic epithelium—we may note that the one factor of that double entity, viz. the cœlomic epithelium, can always be traced to the enteron or to the primitive enteric cell, whilst the other factor may be (1) wholly or (2) partially fused, as we have above explained, with the enteron, or (3) entirely independent of it. Such part of the musculo-skeletal factor as is not appropriated by the enteron *may still continue* to arise by delamination from a fully-formed ectodermic cell-layer, or may appear in the very early stages of development as independent cells, having segregated before the cell-division of the embryo had advanced very far. In Pisidium, Paludina, Limnæus, and other Invertebrates, it appears very probable that, whilst a large part of the musculo-skeletal tissues arise from the parentera with which their elements have become associated through precocious segregation, other parts of the musculo-

ture and connective tissues continue to take origin by delamination from ectodermal cells at later stages.

In all the large groups of the animal series, excepting the Cœlentera and Echinoderma, a very great diversity in this matter prevails.

III. Considerations relative to the Development of External Form.

A. *Radial and bilateral symmetry and telostomiate and prostomiate conditions.*—It has been recognised by various writers, but notably by Gegenbaur and Haeckel, that a condition of radiate symmetry must have preceded the condition of dilateral symmetry in animal evolution. The Diblastula may be conceived to have been at first absolutely spherical with spherical symmetry. The establishment of a mouth lead necessarily to the establishment of a structural axis passing through the mouth, around which axis the body was arranged with radial symmetry. This condition is more or less perfectly maintained by many Cœlenterates, and is reassumed by degradation of higher forms (Echinoderms, some Cirrhipedes, some Tunicates). The next step is the differentiation of an upper and a lower surface in relation to the horizontal position, with mouth placed anteriorly, assumed by the organism in locomotion. With the differentiation of superior and inferior surface, a right and a left side, complementary one to the other, are necessarily also differentiated. Thus the organism becomes bilaterally symmetrical. The Cœlentera are not wanting in indications of this bilateral symmetry, but for all other higher groups of animals it is a fundamental character. Probably the development of a region in front of, and dorsal to, the mouth, forming the PROSTOMIUM, was accomplished *pari passu* with the development of bilateral symmetry. In the radially symmetrical Cœlentera we find very commonly a series of lobes of the body-wall or tentacles produced *equally*—with radial symmetry, that is to say—all round the mouth, the mouth terminating the main axis of the body—that is to say, the organism being "telostomiate." The later fundamental form, common to all animals above the Cœlentera, is attained by shifting what was the main axis of the body, so that it may be described now as the "enteric" axis, whilst the new main axis, that parallel with the plane of progression, passes through the dorsal region of the body, running obliquely in relation to the enteric axis. Only one lobe or outgrowth of those radially disposed in the telostomiate organisms now persists. This lobe lies dorsally to the

mouth, and through it runs the new main axis. This lobe is the PROSTOMIUM, and all the organisms which thus develop a new main axis, oblique to the old main axis, may be called prostomiate.

I have introduced these considerations relative to the changed structural axes of prostomiate, as compared with telostomiate organisms, in order to make clear what follows relative to ciliated bands and tentacles.

b. Ciliated bands and tentacles; identity of these structures in Echinoderms and Vermes with the gill-tentacles of Polyzoa, Brachiopods, and Lamellibranchs; hypothesis of the Architroch.—To Professor Huxley we owe the first perception of the identity of the ciliated bands of the Pluteus larva with the "wheel apparatus" of the Rotifera. Gegenbaur, in his 'Grundzuge,' further showed most ingeniously how two ciliated bands surrounding the embryo, one in front of and the other behind the mouth, could be derived from one single circlet circumscribing the mouth, and how, further, the hinder of the two circlets might be suppressed, leaving only a præoral circlet, which I have proposed[1] to call uniformly the "velum," whether it appears in Mollusc, Annelid, Rotifer, or Echinoderm.

It does not require very long consideration, in these days of the triumph of the doctrine of "uniformity of type in the structure of animals," to see that it is probable enough that *all the ciliated bands of Invertebrate embryos, and even of adult organisms, can be explained as derivatives of one primitive organ.* By "ciliated bands," I mean, not secondary and unimportant ciliated tracts, but those strongly marked ciliated ridges often drawn out into successive tentacula, which are at one time or other *dominant* organs in the animal possessing them, and which may remain throughout life as chief instruments in the economy. Such ciliated bands are the bands and processes of Echinoderm larvæ, the ciliated girdles of many Annelid embryos, the tentacles of Phoronis, and the tentaculated organ of Actinotrocha, the ciliated trumpet of Gephyræans, the "velum" of Molluscan embryos, the similar apparatus of Rotifera, the crown of tentacles of the Polyzoa, the gills and labial tentacles of the Lamellibranchia, and the spiral arms of the Brachiopods.

All these forms can, it appears to me, be derived from a ciliated girdle, which was developed, in all probability, around the ancestral organism by a specialisation of the ciliated ectoderm, at a time when the organism was telostomiate.

[1] "Development of the Pond-snail." 'Quart. Journ. Mic. Sci.,' 1874.

The telostomiate planula, I conceive, ceased to develop cilia uniformly over its body-surface and acquired a special circlet of these appendages, not far distant from the mouth (Pl. XXV. fig. 1). The shifting of the main axis and acquirement of the prostomiate condition during later development would bring about the form now exhibited in the early phases of the ontogeny of Echinoderms, with which Gegenbaur starts his consideration of the subject. This form of girdle with the mouth in its centre may be termed the "Architroch" (figs. 2, 3). I cannot call to mind any existing representative of a *telostomiate* architrochophor (the cyclostomous Polyzoa are so only by recurrence), but the early stages of Echinoderms are *prostomiate* or *metaxial* architrochophors. So, too, is Actinotrocha, whilst the tentacles of Phoronis are simply an architroch drawn out into filaments. The gill filaments of the Polyzoa, with hippocrepian, and circular lophophor, alike correspond to a complete architroch drawn out into more numerous processes than we find in the Pluteus-larvæ or in Bipinnariæ, and must not be mistaken in consequence of their filamentary modification (figs. 17, 19). This development of tentacle-like filaments along the line of the ciliated band is a quite common, indeed, characteristic feature of the architroch and the circlets into which it divides. Thus in Rotifers (Stephanoceras), and in Gastropod embryos (Macgillivrayia, Ethella), the 'velum' is drawn out into filamentous ciliated tentacles (fig. 15).

The gill-filaments of the Lamellibranchs, *together with* the labial tentacles, form an incomplete architroch (fig. 16). To be complete the line of origin of the double set of gill-filaments which form the gill-plates,[1] should be continued on each side behind the foot (between the foot and anus). At this part the Lamellibranch's architroch is broken, but this will not appear surprising when the case of Rhabdopleura (see this Journal for 1874) is considered, in which alone, amongst Polyzoa, the architroch is incomplete and reduced to a pair of plume-like appendages; still less is it to be wondered at that the architroch should be broken through at this point, when we consider the enormous development of the muscular lobe within the architrochal area, the foot, truly a hypertrophied chin.

An important consequence of the view now advanced as to the nature of the gill-filaments of acephalous Mollusca is the serial homology of the labial-tentacles of Lamellibranchs with the gill-plates of the same animals. Continually all sorts of special homologies have been proposed for these

[1] See Holman Peck, this Journal, January, 1877.

organs. In reality, they are only specially modified parts of the architrochal band, not giving rise to filaments, but by a late modification of an original series of filaments giving rise to spongiose erectile lobes. They complete, anteriorly or præorally, the architroch of the Lamellibranch.

The reduction of the filiferous architroch in the Polyzoan Rhabdopleura to a plume is of the greatest importance, because *it allows us to assume, in other cases, that branchial plumes have possibly been developed by reduction of an architroch.*

Whilst the larvæ of certain Echinoderms (the Pluteus and Auricularia of Echinids and Holothurians) are architrochic, the Bipinnaria and Brachiolaria of Asterids present us with an important modification of the primitive condition, as does also the Auricularia of Holothurians, when it passes into the polytrochous condition. The ring surrounding the mouth becomes drawn out in such a way that it extends round the larva on each side (fig. 4), and its two extremities meeting and joining we have, as Gegenbaur has shown, two rings developed, whose plane is at right angles to that of the original single peristomial ring from which they develop. The anterior circle embraces the prostomium, the posterior, which is usually larger and oblique in direction, is metastomial. We find in the Echinoderms very near approaches made to this breaking of the architroch by a dorsal nipping-in, without the actual fusion being accomplished. I propose to call that condition of the cillary tract in which the fusion *is* accomplished "zygotrochic." The Asterid larvæ (fig. 12) are zygotrochic, so it appears is Tornaria (fig. 8), the larva of Balanoglossus. The two secondary circlets into which the architroch divides may be conveniently distinguished as the "cephalotroch" and the "branchiotroch." The "cephalotroch" is also known as the "velum." It is this portion only of the differentiated architroch which makes its appearance in the larvæ of the Gasteropodous Mollusca; it is this part only which appears in the case of many Annelid larvæ and in the Rotifera. The "branchiotroch" is so named on account of the fact that it is this portion of the differentiated architroch which most constantly gives rise to ciliated branchial filaments. Such are the filaments of Actinotrocha (fig. 13); such are the gill-filaments of the Lamellibranchs. I am inclined to think that gill-filaments in the adult, which cannot be directly traced to a larval branchiotroch, in fact, in cases where the larva possesses only a "velum," or cephalotroch, may yet be

regarded justly as modifications of the branchiotroch in consequence of their position and structure alone. The two portions of the zygotroch, once differentiated from the architroch, may have acquired a considerable independence of one another in their development in some races, whilst in the archaic group of Echinoderms they retain a consentaneous growth.

In many Chætopoda, Platyelmia, and Eucephalous Mollusca, the embryo, when still almost spherical in form and diblastulous in structure, acquires the cephalotroch, which takes at this early period the position of an equatorial girdle (Pl. XXV, fig. 6). Such a larval form I have called the "trochosphere." It is clearly not a primitive form, but is derived, by the steps I have just indicated, by a series of adaptations from the telostomiate architrochopor. It is an *adaptational* larval form common to many marine organisms, and indicates that its ancestors must at one time or another, in larval or adult life, have exhibited the following conditions—(1) telostomiate architrochal, (2) metaxial architrochal, (3) zygotrochal, (4) cephalotrochal—that is, suppression of the branchiotroch.

Professor Semper has recently made the attempt to set up this much modified larval form, with its premature cephalic circlet, as an important ancestral form, and has announced a "Trochosphæra theory."

If the views which I have here expressed are well founded, Semper's theory of the trochosphere is not more valuable than his theory of Amphioxus.

Many ciliated larvæ have been called "telotrochic" (figs. 8, 13), in consequence of their possessing a perianal circlet of cilia. Gegenbaur is inclined, though not decisively, to refer this "telotroch" to the architroch, regarding it as the equivalent of the branchiotrochal moiety. This I cannot consider to be justified. The telotroch appears to be a *metameric* repetition of the architroch, or of its branchiotrochal moiety. That such is the case is suggested by the condition of the Tornaria-larva of Balanoglossus. It is possible that the ciliated circlets which are posterior to the area of the architroch or its derivatives, are to be regarded as altogether secondary structures, and indeed they are so upon any view of the case, in so far as metamerism is a secondary condition. Such secondary circlets as the telotroch and the other more or less numerous circlets of polytrochic larvæ, I propose to call "epitrochs," and, accordingly, a ciliated larva, whilst either architrochic or zygotrochic, may be "anepitrochic," or "monepitrochic," or "polyepitrochic."

The most remarkable polyepitrochic larvæ are those to which the Auricularian architrochic larvæ of the Holothurians give rise. The architroch of these larvæ becomes a zygotroch, a distinct cephalotroch or velum, belonging to the prostomial region, being pinched off from the branchial circlet; but this latter, instead of remaining as a single girdle, again breaks up into four circlets by development of cross-pieces in correspondence with a metamerism, often indicated also by the deeply-marked lobulation of the body. It is interesting to note that in this transient metameric segmentation of the Holothurian, the metameres agree with the more fully developed metameres of lineally segmented worms in the fact that, *whilst the first metamere consists of prostomium and metastomium, each succeeding metamere corresponds only to the metastomial portion of the first metamere.* This is clear in the case of the polyepitrochic Holothurian larva, since the metastomial circlets are developed by direct conversion of the metastomial portion (branchiotroch) of the zygotroch. In other polyepitrochic larvæ, as well as in monepitrochic larvæ, the epitrochs develop quite independently of the architroch or its parts. Terebratula and other Brachiopods present us with a polyepitrochic larva having an architroch anteriorly. Actinotrocha has one epitroch and an architroch. The larva of Dentalium possesses a cephalotroch, followed by many epitrochs independently developed. The same is true of some Pteropod larvæ. Many Chætopod larvæ are also in this condition.

It seems to be quite possible that the branchial filaments of Chætopod worms, as well as the branchiæ of the Eucephalous Mollusca, may, like the branchial filaments and plumes of the Acephalous Mollusca and the tentacular crowns of Phoronis and the Gephyræa, be ultimately traceable to the branchiotrochal moiety of the architroch.

Enumeration of the modifications of the Architroch.

A.—Architrochic forms:

1. Anepitrochic—

Pluteus of Echinids and Ophiurids; Auricularia of Holothurian; larval and adult Polyzoa; Lamellibranchs and Brachiopods; adult Phoronis; and also Bonellia, Thalassema, Sipunculus.

2. Monepitrochic—

Actinotrocha.

3. Polyepitrochic—

Larval Brachiopods (Kowalewsky).

B.—Zygotrochic, with separated cephalotroch and branchiotroch:

1. Anepitrochic—

Brachiolaria and Bipinnaria (of Asterids), some Gastropods (?)

2. Monepitrochic—

Tornaria.

3. Polyepitrochic—

Vermiform larva of Holothurians and Comatula.

c.—Cephalotrochic (with suppression of the branchiotroch):

1. Anepitrochic—

Adult Rotifera, the trochosphere larva of Worms and Molluscs, the veliger of Gastropods and Pteropods.

2. Monepitrochic—

The common two-girdled larva of Chætopods.

3. Polyepitrochic—

The polytrochic larvæ of Chætopods, and other worms, as also of Dentalium (Mollusc) and some Pteropods.

IV. The Nephridia or Segmental Organs of the Enterozoa.

In all classes of the Enterozoa there are other openings, usually small, into the cavity originally belonging to the archenteron, besides the mouth and the anus. In those Cœlentera which foreshadow the cœlom by developing a periaxial extension of the enteron or a pericnteron, we find such apertures especially associated with the rudimentary cœlom. In the Actinozoa such apertures exist in the tentacles or at the aboral pole. In some Ctenophora two canals open from the as yet unspecialised cœlom to the exterior by two apertures placed at the aboral pole.

When once the cœlom is accomplished as a cavity definitely shut off from the "metenteron"—the name we now give to what remains of the archenteron—its communications with the exterior acquire a more important character. Whether it be that the respiratory trees or that the orifices of the ambulacral system in Echinoderma represent the communications established between the cœlom and the exterior in the Cœlonata, this appears certain, that in Rotifera, Flatworms, Gephyræa (*not* the genital ducts), Mollusca, in the metameres of Chætopoda, in the Vertebrata, and even in some Arthropoda, we have evidence of the existence of a single pair of canals more or less highly modified by glandular developments, which usually open by ciliated funnel-like mouths into the cœlom at one end and directly to the exterior in the neighbourhood of the anus, or into a cloacal chamber, at their other end, thus placing the cœlom in communication with the exterior.

This pair of ciliated funnels appears to be the same organ in all cases.[1] Primarily it develops like the stomodæum and proctodœum by an ingrowth of the ectoderm or deron. At present no name is in use for this important pair of organs; they are spoken of as "segmental organs" in some groups, as "primitive excretory organs" in others. Since very usually these canals acquire an excretory function and give rise to kidneys, though they may also serve as genital ducts, I propose to call them by the diminutive of the Greek word for a kidney—namely, "nephridium." The nephridia in Rotifers, and Turbellarians and Trematods, are the ciliated canals, though in the flat-worms it is impossible to say where in the canal system "nephridium" ends and "cœlom" begins. In Chætopoda the nephridia are the segmental organs, in Gephyræa the pair of organs opening into the cloaca, in Lamellibranchs they are the organs of Bojanus, in Brachiopoda they are the oviducts (so-called hearts), in Gasteropods they appear, at any rate, in the embryo, in many cases (Urnieren). In tracheate Arthropods the Malpighian filaments possibly are the nephridia, whilst the Vertebrate kidney and genital ducts have recently been traced by Balfour and Semper to a series of nephridia.

The terminology of the new doctrine as to the Vertebrate genito-urinary canals appears to me to need some clearing up, and I therefore submit the following:

The metameric segmentation of the primitive Vertebrate gives us a series of nephridia, derived from one single pair of nephridia in the still earlier unsegmented Vertebrate. The nephridia are not, however, in the metameric Vertebrate separate from one another, each with its own external aperture, as in Chætopod worms, but all (on one side) are developed on a common stem or duct, so that they form one organ on each side of the animal. This compound organ is a kidney; it may be called the "archinephron," its duct the "archinephric duct." By longitudinal fission parallel with its axis, the archinephric duct splits into two—one, the "pronephric duct," in connection with the more anterior nephridia which form the "pronephron;" the other, "the mesonephric duct," in connection with the posterior nephridia, forming the "mesonephron." The pronephron (Kopfnieren) aborts, the pronephric duct becomes the oviduct; it is frequently called Müller's duct. The mesonephron is the Wolffian body, its duct the Wolffian duct. Its anterior

[1] Gegenbaur recognises two kinds of primitive excretory organs which, if really distinct, might be called 'anterior' and 'posterior nephridia' respectively.

nephridia form the ducts for the testis. Finally, a metanephron, with metanephric duct distinct from the Wolffian or mesonephric duct, may develop by a later increase of nephridia posteriorly. This metanephron with metanephric duct exists in sharks; in abranchiate Vertebrates it becomes the permanent kidney, and its duct the ureter.

V. Later development of the Deron and Enteron.

In what has preceeded we have given the outline of the cellular foundations of the superficial and deep tissues of the body-wall—of the lining membrane and corpuscles of the lymphatic hæmal spaces and vessels, and of the internal and external tissues of the alimentary tract.

Origin of Nerve-tissues.—It only remains to point out briefly, in order to complete this sketch, that the ectoderm having broken up (as we saw above) into epiblast and the musculo-skeletal portion of the mesoblast—or, as we may put it, into neurodermal and myoskeletal moieties—now proceeds further in differentiation. For the neurodermal tissue, which in position is the true representative of the original ectoderm, now separates into neural and dermal groups of cells. This does not, however, occur by a general splitting of the neuroderm or epiblast, but by *localised* differentiation. In all classes of organisms possessing nerve-centres or masses of nerve ganglion-cells these structures have been traced in development to the neuroderm or epiblast. It is probable that primitively the whole nervous apparatus is to be traced to epiblast, and that where (as appears very frequently to be the case) masses of nerve-cells and fibres arise deeply by differentiation of cells lying in the mesoblast, such nervous structures are not to be supposed to have taken their origin by a gradual metamorphosis of musculo-skeletal or of vascular elements, but their present ontogenetic development at points devoid of direct connection with epiblast is to be explained as we have explained other shiftings from ancestral connections—namely, by a very early passing over of hereditary nervous molecules from cells destined to form epiblast into cells destined to form mesoblast.

In all Prostomiata, or, what is same thing, in all Bilateria or cœlomate Enterozoa, the main tracks occupied by the differentiated nervous tissue have the same position. They appear primarily as paired laterally placed centres within the prostomium. From them radiate fibrous tracts. Their further development consists in elongation, so that they become lateral cords, and the fibrous and spherical

cell-elements which make up nerve tissue may be evenly distributed along these tracts, or the spherical elements may be concentrated at important points in obedience to the proportions assumed by other parts of the body, *e. g.* metameric segmentation of muscles, or development of a mesopod (molluscan foot), or of a special sense organ. The lateral tracts once established show the strongest tendency to unite into a single tract by gradually taking up a median position. This junction of the lateral tracts may occur either dorsally or ventrally, and the result is the production of a dorsal or of a ventral nerve mass. In most of the higher Enterozoa the junction is effected dorsally in the region of the prostomium and ventrally in the metastomial region. Cases of very partial or altogether ineffective fusion of the metastomial portions of the nerve tracts are common.

Archenteron, Parentera, Metenteron, Mesenteron, and *Hepatic Cæca*—The successive differentiations or subdivisions of the original digestive cavity (archenteron), lined by the endoderm or enteric cell layer, may be rapidly summarised as follows:—The archenteron (Urdarm) breaks up into the two (subsequently fused) *parentera* and the axially-placed *metenteron.* The parentera become cœlom, the metenteron retains digestive functions. The parentera form cœlomic and vascular epithelium, blood-corpuscles and female reproductive tissue (ova). According to Ed. Van Beneden the male reproductive tissue is formed from ectodermal (deric) cells. The metenteron is joined by stomodæum and proctodæum, and now gives rise in a large number of cases to two cæcal outgrowths (the hepatic cæca), often of great size, which resemble in some cases the cœlomic parentera. According to the view here taken, however, they have nothing to do with the cœlomic parentera, but are of much later origin. They become widely separated in character from the rest of the metenteron, which must now be distinguished as *mesenteron,* and continue to open into it by a narrow passage, through which their secretion passes. Thus, then, as archenteron divides into parentera and metenteron, so metenteron divides into *hepatentera* or hepatic cæca and *mesenteron.*

Other diverticula to which the mesenteron gives rise do not require notice here. The salivary diverticula, it may be well to note, are parts of the stomodæum, whilst the glandular cæca, ducts, and tooth-like hardenings, which belong to the sexual organs very generally, are developed from the proctodæum just as similar parts belonging to the mouth develop from stomodæum.

VI. The more general Causes and Modes of Development.

In the preceding sections of this essay we have discussed the probable succession of forms and the particular phases of increasing complexity which animal organisms have presented in the course of their historical development, and an attempt has been made to show that the phenomena of individual development from the egg may be considered as more or less slurred and interrupted recapitulations or epitomes of the historic development.

Now, let us take a more general point of view, and endeavour to state *what* are the more general causes or antecedents of organic development, and what the more general effects of those causes, that is to say, the *modes* of their operation; so we shall come nearer to the ultimate goal of biology which is the accounting for the phenomena of living matter or protoplasm by reference to the laws of chemistry and physics.

In order to look at development from the physiological point of view it is necessary to take a glance at the structure of organisms in relation to their activities.

The following propositions contain the essential doctrine of the interdependence of structure and function.

1. Every organism is either a single corpuscle of protoplasm or an aggregate of such corpuscles, variously modified.

2. A corpuscle of protoplasm or "unit of organic structure" is called a plastid. A plastid which possesses a differentiated kernel or nucleus is called a cell; one devoid of nucleus is called a cytod.

3. The living substance of all organisms, whether consisting of many or of one single plastid, exhibits the following activities, which are explained by its chemical and physical constitution:—1. Contractility. 2. Irritability. 3. Reception and assimilation of foreign matter. 4. Chemical change and secretion. 5. Respiration, *i. e.* combination with oxygen and excretion of carbonic acid. 6. Reproduction, either resulting in growth or, when accompanied by self-division, in multiplication of individuals.

4. In the lowest organisms, which consist of one single plastid, these various activities are carried on by one and the same corpuscle of protoplasm. In the higher organisms, consisting of many plastids, they are exhibited more or less clearly by each and all, but are intensified variously in particular plastids. According to their position and the particular

activity which they pre-eminently exhibit, the plastids of such an organism vary in form, and the nature and amount of chemical change to which the protoplasm composing them has been subject varies also. They may be spherical, columnar, prismatic, scale-like, star-shaped, spindle-shaped (fusiform), branched, or united to form fibres. The substance between the plastids may be absent (when the plastids are continuous), very small in amount or large in amount. It may be solid and dense, or gelatinous and viscous, or fibrous or liquid.

5. When a number of plastids exhibiting pre-eminently one kind of activity (see sec. 3), and having one particular form and one particular kind of intermediate substance (if any) are found forming a layer or separable tract in an organism they are said to constitute a TISSUE.

6. In a higher organism the activities enumerated in sec. 3 (each of which is exhibited more or less by each of its constituent plastids) are carried on through the agency of a number of specially adapted parts, which are known as ORGANS. Every organ has its FUNCTION in relation to one or other of these activities. Many tissues may enter into the composition of an organ. A series of connected organs forms a SYSTEM.

7. The development of organisms (of which in the earlier part of this essay we have traced the concrete expression, so far as relates to animals) is primarily caused by the advantage gained for an organism in the struggle for existence by the distribution of the activities specified in sec. 3—amongst special parts, that is to say, by the advantages gained by the possession of elaborate tissues and organs.

8. The possibility of development is solely due to the physico-chemical constitution of protoplasm, in virtue of which constitution it is subject to (A) *unlimited Variation* by the action of incidental forces, and to (B) the *permanence of impressions* or *Memory*. In virtue of the memory of protoplasm, *fortunate* variations, acquired in the life-and-death conflict with the environment, become *permanent* adaptations in such organisms as survive (survive as individuals or as new generations). Those with unfortunate variations die off in consequence of the want of fitness of their variations (both newly acquired and constitutional) to the conditions presented by the struggle for existence. Thus the selection of new variations, and the constant accumulation of old-acquired improvements by the operation of the protoplasm's memory in the survivors of the struggle for existence goes on. The elaborate distribution of functions amongst specialised

parts of the organism has been in this way slowly built up. The final advantage of highly complicated structure has been gained by certain representatives of the animal and the vegetable pedigree through Adaptation, due to the property of unlimited variation, and through Heredity, which is only another name for Memory or permanence of impression, as manifested by the detached reproductive bits of an organism.

9. The process of the development of new tissues or new organs in a race of organisms where such tissue or organ has no previous existence, must follow certain definite methods. From the nature of the causes at work (secs. 7 and 8), the new development must be excessively gradual. It may be taken as a law of development that no *really new* part *ever* does make its appearance, every apparently new tissue or organ which may strike the morphologist as novel, being necessarily only a modification of a pre-existing tissue or organ. The absolute continuity of forms is a deduction from the law of evolution, and the hypothesis of unity of organization.

The processes of differentiation by which organisms acquire modifications in structure, may be grouped under the following general heads: (1) Polar Repetition of units of structure. (2) Segregation of chemically and physically differing materials. (3) Hypertrophy and Atrophy of parts relatively to one another. (4) Concrescence (of polar units or of appendages and tissues).

Polar Repetition stands first in this list, since it is dependent on one of the most important and distinctive features of protoplasm, with which only crystalline polarity can be compared. The existence of multicellular organisms instead of large unicellular organisms is due to the peculiar conditions of molecular cohesion in protoplasm; in fact, the polar repetition of the simplest organic unit is at the bottom of all the higher organic differentiation. Further, we find that the groups formed by the primary units or plastids, and which Herbert Spencer calls "aggregates of the second order," may, like the primary units, cease to grow indefinitely as secondary units, and, with or without fission, the growing secondary unit arranges itself as a *number* of such secondary units (in line as in worms, or irregularly as in polyp-trees, or radially as in compound Tunicates), and itself becomes "an aggregate of the third order."

Thus the polarity of protoplasm is a very important element in the differentiation of organic forms.

Segregation may slowly bring about a difference in the substance of two portions of the same unit, and at last estab-

lish the sharpest demarcation between such portions; all separation of constitutional and structural elements at one time united comes under this head.

Hypertrophy and *Atrophy* are the most obviously efficient methods of differentiation when once a beginning has been made, either by polar repetition or mere segregation. Hypertrophy enlarges one unit or set of units, whilst the rest remain stationary, or the one half of a cell already differentiated by segregation is atrophied, whilst the other is hypertrophied.

By Atrophy cilia disappear from the surface of the body, and become confined to a single band; by Hypertrophy this band becomes drawn out into filamentous tentacles.

The majority of developmental differentiations, which the careful study of ontogeny and the cautious use of the "recapitulation hypothesis" enable us to infer as having historically occurred in the course of animal evolution, can be reduced to terms of Hypertrophy and Atrophy.

Concrescence finally, though a less striking, is by no means a less important form of structural modification than those which we have already noticed. Concrescence undoes the work of Polar Repetition and Segregation. By it multicellular tissues become syncytia, segmented animals lose all trace of their segments, or their segmentation becomes obscured and obliterated over large tracts.

This is the process exhibited in the fusion of nerve-ganglia, in the adhesion and combination of gill-filaments and in the substitution of one continuous unit for a number. In the last case it is not to be confused with hypertrophy and concurrent atrophy.

VII. Classification.

Classifications of many kinds are possible and convenient for various purposes in reference to the series of animal forms. A classification may be said to be "subjective" or to derive its importance from subjective relations which sets up some particular characters chosen for reasons best known to the person who chooses them, as the test-points in reference to which animals shall be classified. It has only lately been recognised as possible (namely since the fact has been admitted, that all living and extinct organisms are members of one great family tree) to investigate the claims of a system of classification to acceptance by reference to an objective standard. Whilst many classifications may be and are termed "objective" (because they are logically correct), which, in consequence of their being

purely mental abstractions, *arbitrarily* chosen from many many possible abstractions, would be more justly named "*subjective*;" yet there is one objective classification possible, which is no mental abstraction, but as corresponding with the actual order in which the objects of classification were brought into existence may claim to be the objective and natural classification *par excellence*. This classification would be *exhibited* in a complete statement of the pedigree of the animal kingdom.

It is certain that we shall never be able to set forth with anything like completeness this real or objective genealogical classification. Accordingly, all our attempts at it may be called, as they have been, subjective classifications, since they depart from the objective reality in proportion as our imagination has to supply the gaps in our knowledge—in proportion as in them inference is given a particular form where our acquaintance with fact only justifies a general form. But it is clear enough that in its broad outlines we are likely enough as knowledge increases to make our genealogical classification correspond with the reality if we consistently aim at that object.

What there is of objective in such classifications is at any moment capable of being tested and discussed, whereas classifications which ignore genealogical speculations, though they may claim indisputable objectivity as their justification, yet fail to commend themselves equally to their authors and to contemporary naturalists. Such classifications may be as [illegible] they are true, but, after all, their utility is measure[illegible] approximation which they make to the formula[illegible] that they profess to ignore, namely, the pedigree. [illegible] that set forth in this kind of classification, how[illegible]putable, is one of small or even over-estimated [illegible]

[illegible] if we [illegible] with Mill that the higher kind of [illegible] is [illegible]ich seeks "to arrange objects in such [illegible] in such an order as will best con[illegible] and remembrance of their laws," [illegible]lassification of animals which keeps [illegible] in view is more likely to be [illegible]onduce to the ascertainment and [illegible]rations than one which expressly [illegible]

[illegible]—*Progression and degeneration.* [illegible] up a true pedigree of the animal [illegible]gh that we are seeking to trace the [illegible] we must proceed primarily on

the assumptions (1) that organisms of like structure—that is, with like adaptations—are related to one another by blood with a degree of closeness which is in direct proportion to the closeness of the likeness; (2) that the general effect of evolution in relation to organisms has been to effect a progress from simpler structural conditions to more complicated, whence it is inferred that the more simple organisms which to-day exist are surviving representatives of the earlier phases of organic evolution, the race to which they belong never having attained a higher level than it does to-day, and that all existing organisms may be arranged according to the degrees of complication of their structure in several ascending series, the degrees in which represent so many stages attained to and passed through by the ancestors of the most highly complicated member of the series.

Having started with these two assumptions, as all those who have attempted phylogenetic classification have done, it is very soon found to be necessary to qualify and relax the general application of both the principles assumed. It is very soon recognised (and, indeed, is universally admitted) that there are many cases of a pair of organisms which are, on the whole or as to some striking detail, alike in structure—that is to say similarly adapted—and yet (as we learn from their developmental history or from some one indisputable structural feature) do *not* owe that similarity to heredity, but to an independent identity in adaptation occurring in the two cases in consequence of a recurrence of the same adaptational conditions. Such similarity is said to be due to homoplasy,[1] whilst hereditary likeness is due to homogeny. In phylogenetic classification, then, we have to be especially on our guard against mistaking homoplastic for homogenetic agreements.

An "objective" method of classification which should ignore the doctrine of evolution could not fail to confuse organisms related by homogeny with others related to them only by homoplasy; and, indeed, this was notoriously the case with the classifications of the first half of this century.

Again, as to the second assumption of "a continuous progression" in all the myriad branches and twigs of the organic family tree—the assumption of a continuous flow *onwards* (slower or faster, but always forward) in all the multifarious streamlets into which the original stream of life has subdivided, this, too, has been universally qualified. It has been admitted in certain very obvious cases, *e. g.* many

[1] This term was first proposed in my article "On the Use of the term Homology in Modern Zoology," 'Annals and Mag. Nat. Hist.,' 1870.

parasitic and sub-parasitic animals, that there has been a *reversal* of the stream of development, and that *these forms are the result, not of progressive adaptation, but of retrogressive adaptation or degeneration.*

In regard to both assumptions, the qualification has been admitted grudgingly and insufficiently up to the present time. It is not, as a rule, sufficiently conceded that homoplasy is as much a *vera causa* of structural likeness as homogeny, and that, whilst we pursue the logical method of assuming (to begin with) a uniform cause—namely, homogeny—in order to account for structural likeness, yet we should be on the alert whenever difficulty arises in the consequences deduced in a particular case from the employment of homogeny, to test at once the applicability of homoplasy.

Thus Mr. Jhering, appropriating to himself the doctrine and the term "homoplasy," has suggested that, in the group of the Mollusca (as usually recognised by naturalists), are included two homoplastic groups of totally different origin. There is nothing improbable in this application of the doctrine of homoplasy, and indeed I am inclined to think that some such application of it to the group of the Arthropoda is the only escape from the difficulties which the hypothesis of homogeny presents in regard to that group. With regard, however, to the Mollusca, Mr. Jhering appears to have been singularly unfortunate in the skill which he has displayed in using borrowed tools. The two homoplastic groups which Mr. Jhering fancies he has detected under the common type Mollusca have each of them, according to him, *independently developed that very remarkable apparatus, the lingual ribbon, with its cushions and muscles.* Such an assumption is entirely devoid of justification. We see in Mr. Jhering's case an interesting exhibition of the necessity for ascertaining and respecting the limits within which homoplasy may reasonably be assumed as a possible cause of structural identity in a comparison of organisms. We know of no case in which there is any ground for inferring that homoplasy—that is, independent adaptation—has produced two structures so complex and varied in detail and yet so absolutely the same in all respects as are the lingual apparatus of Chiton, on the one hand, and of the normal Gastropoda, on the other. The assumption, without any collateral evidence in its favour, of such potency for homoplasy, is a violation of common sense, sufficiently reckless, even without the employment of folio paper, to give to its perpetrator a temporary notoriety.

We have every reason to hold homoplasy responsible for the agreement (such as it is) between the beak of the turtle and the beak of the bird, between the gill-plate of Lamellibranchs and the pharynx of low Vertebrates, between the segmentation of some Platyelmia and the segmentation of Appendiculata, possibly for the change of legs into jaws in Crustacea on the one hand and in Tracheata on the other, or possibly for the development of tracheal tubes once in Peripatus, and also a second time in Insects; but in none of these cases are we led to ascribe anything to homoplasy beyond the production of *very general* or *very simple* agreements, and until we have reasons for supposing that it can act continuously and cumulatively so as to produce *elaborate* correspondences, we are clearly not justified in assigning this power to it in a particular case.

It is chiefly through the valuable pamphlet of Anton Dohrn[1] that attention has been directed to the logical necessity of admitting the possibility of very widely prevalent degeneration. At present naturalists are so very generally persuaded (by habit, not by reason) of the universality of progression—that no one has attempted to face the counter theory of universal degeneration which Dohrn put forward.

Whilst this theory is passed over with silent contempt it appears to me to have as strong a logical position as the theory of universal progression. The evidence of degeneration is admitted as conclusive in the case of the parasitic Crustacea and Cirrhipedes. It is equally incontestable in that very large and varied group of non-parasitic organisms, the Tunicata (Urochordate Vertebrata).[2] The destruction of a very few forms from among the Tunicates would leave us without the evidence of their degeneration. We should then, on the assumption of the prevalence of progression, regard the Tunicates as representing the highest pitch of structural complexity to which their race had attained, and assign them an erroneous position. Obviously, we must be liable to make this mistake with regard to every isolated group, but especially liable to do so in the case of very small groups or isolated genera of simple structure. So strong is the case in favour of degeneration, that at present all that can be said against it and in favour of progression, with regard to any

[1] 'Ursprung der Wirbelthieren.'

[2] The whole argument as to the Tunicates of course rests on the view supported by many arguments, that the larval urochord, which many of them possess, is *not* a larval organ acquired by larval adaptation, but is hereditary and transmitted from adult ancestors.

particular case, is this—that the general doctrine of evolution justifies us in assuming, at some period or other, a progression from the simplest to the most complicated grades of structure; that we are warranted in assuming at least one progressive series leading from the monoplast to man; and that *until we have special reason* to take a different view of any particular case we are bound to make the smallest amount of assumption by assigning to the various groups of organisms the places which they will fit into, on the supposition that they do represent in reality the original progressive series. Nevertheless, any naturalist would find it very difficult to prove, or render highly probable, that many of the Protozoa are *not* descended from Enterozoa by degeneration; that Dicyema is *not* a degenerate flat worm; that the whole race of corals and polyps are *not* degenerate descendants of far more highly developed, worm-like, free-swimming ancestors.

When, therefore, the hypothesis of degeneration presents itself as a solution of any special morphological difficulty, we need have no scruples or prejudices in favour of the doctrine of universal progression, which should prevent us from accepting it.

In the following tables of classification I have made use of the term "phylum," proposed by Haeckel, instead of "sub-kingdom," "embranchement," or "typus." The phyla are so many great diverging branches of the family tree of animals. Classes are the branches borne by phyla, orders are the branches borne by classes. I have introduced the term "branch" as an equivalent for subphylum, or subclass, as the case required.

The most important explanation which is necessary here is with regard to the terms "grade" and "appendix," which I have frequently introduced. Whilst all the other terms indicate branches of the pedigree diverging from a very nearly common point (thus all the classes in a phylum are supposed to diverge from one common point unless it is otherwise indicated), the various "grades" are introduced to separate the starting-points of the branches; a certain advance in differentiation of structure separates the branches of a higher grade from those of a lower. An 'appendix' is an assemblage of 'degraded' examples of the group to which it belongs.

Tabular View of the Phyla of the Animal Kingdom.

ANIMALIA.

Organisms incapable of assimilating either N or C from their simpler water-soluble compounds, and therefore provided (excepting parasites) with the means of ingesting and acting upon the solid substance of other organisms.

Grade I.—PLASTIDOZOA.

Animals consisting of single plastids, or of groups of plastids not differentiated into cell-layers.

PROTOZOA.

Grade II.—ENTEROZOA.

Animals consisting of many plastids primarily arranged in two layers surrounding a food-receiving cavity—the enteron (the lumen of which is obliterated in some parasites).

Grade 1 (of the Enterozoa) CŒLENTERA (Diploblastica).

Enterozoa in which the enteron remains as a continuous cavity, either simple or much ramified, coextensive with the body wall. Persons telostomiate, generally with radial symmetry.

Phylum 1.—PORIFERA.
" 2.—NEMATOPHORA.

Grade 2 (of the Enterozoa) CŒLOMATA (Triploblastica).

Enterozoa in which a second cavity containing hæmolymph—viz. the cœlom—entirely shut off from, though in its origin a part of, the enteron, is developed between the body wall and the enteric wall. Persons primarily prostomiate, bilaterally symmetrical, with paired nephridia and nerve tracts.

Phylum 1.—ECHINODERMA.
Branch *a*. Ambulacrata.
" *b*. Tentaculata.

Phyl. 2.—PLATYELMIA.	*Phyl.* 4.—GEPHYRÆA.	*Phyl.* 6.—ENTEROPNEUSTA.
Br. *a*. Ciliata. " *b*. Suctoria.		
3.—APPENDICULATA (PARAPODA). Br. *a*. Chætopoda. " *b*. Rotifera. " *c*. Gnathopoda.	5.—MOLLUSCA (MESOPODA). Br. *a*. Encephala. " *b*. Lipocephala.	7.—VERTEBRATA. Br. *a*. Urochorda. " *b*. Cephalochorda. " *c*. Craniata.

Phyl. 8.—NEMATOIDEA. *Phyl.* 9.—CHÆTOGNATHA.

N.B.—On account of their very dubious affinities and probable degeneration, no attempt is made in the above synopsis to include the following forms: the Gastrotricha (Chætonotus, &c.), Desmoscolex, Echinoderes and the parasites Dicyemida and Echinorhynchus.

Classes and Orders of the PROTOZOA.

Grade A. Gymnomyxa.

Class.	*Order.*	*Examples.*
I. Gymnomyxa	1. Homogenea	*Protomyxa.* *Protamœba.*
	2. Reticularia	*Pleurophrys* *Miliola.* *Nummulites.*
	3. Amœboidea	*Arcella.* *Pelomyxa,* *Amœba.*
	4. Flagellata	*Monas.* *Anthophysa.*
	5. Catallacta	*Magosphæra.*
	6. Labyrinthulida	*Labyrinthula.* *Chlamydomyxa.*
	7. Radiolaria	*Sphærozoon.* *Acanthometra.* *Actinospherium.*

Grade B. Corticata.

I. Corticata	Gregarinidæ	*Monocystis.* *Gregarina.*

Grade C. Stomatodea.

I. Suctoria	Suctoria	*Acineta.* *Ophryodendron.*
II. Ciliata	1. Holotricha	*Opalina.* *Trachelius.*
	2. Heterotricha	*Stentor.* *Paramœcium.*
	3. Hypotricha	*Euplotes.* *Schizopus.*
	4. Peritricha	*Vorticella.* *Peridinium.* *Codonella.*
	5. Calycata	*Torquatella.*
III. Proboscidea	Noctilucida	*Noctiluca.*

Classes of the PORIFERA.

I. Calcispongiæ	*Ascon.* *Leucon.* *Sycon.*
II. Fibrospongiæ	*Euspongia.* *Spongilla.* *Thethya.* *Euplectella.*
III. Myxospongiæ	*Halisarca.*

[illegible]

[illegible]	[illegible]	[illegible]
I. [illegible]	1. [illegible]	[illegible]
	2. [illegible]	[illegible]
	3. [illegible]	[illegible]
II. [illegible]	[illegible]	[illegible]
III. [illegible]	[illegible]	[illegible]
IV. [illegible]	1. [illegible]	[illegible]
	2. [illegible]	[illegible]
V. [illegible]	1. [illegible]	[illegible]
	2. [illegible]	[illegible]
	3. [illegible]	[illegible]
VI. [illegible]	1. [illegible]	[illegible]
	2. [illegible]	[illegible]
	3. [illegible]	[illegible]
	4. [illegible]	[illegible]

[illegible]

I. [illegible]	1. [illegible]	[illegible]
	2. [illegible]	[illegible]
II. Echinoidea	[illegible]	[illegible]
	1. [illegible]	[illegible]
	2. [illegible]	[illegible]
	[illegible]	[illegible]
	1. [illegible]	[illegible]
	2. [illegible]	[illegible]
	[illegible]	[illegible]
	1. [illegible]	[illegible]
	2. Spatangidæ	[illegible]

Class.	Order.	Examples.
III. ASTEROIDEA	Grade A.	*ASTERIÆ.*
	1. Colastra .	*Uraster.*
		Solaster.
		Astropecten.
	2. Brisingastra .	*Brisinga.*
	Grade B.	*OPHIURÆ.*
	1. Ophiastra .	*Ophiura.*
		Ophiothrix.
	2. Phytastra .	*Euryale.*
		Saccocoma.
	***Branch* B. TENTACULATA.**	
I. CRINOIDEA .	1. Tessellata .	*Cyathocrinus.*
		Marsupites.
	2. Articulata .	*Comatula.*
		Rhizocrinus.
II. BLASTOIDEA	1. Elœacrina .	*Elœacrinus.*
		Pentatrematites.
	2. Eleutherocrina	*Eleutherocrinus.*
III. CYSTIDEA .	1. Agelacrina .	*Hedriaster.*
		Hemicystites.
	2. Echinencrina .	*Sphæronites.*
		Stephanocrinus.

CLASSES AND ORDERS OF PLATYELMIA.

Class.	Order.	Examples.
	***Branch* A. CILIATA.**	
I. PLANARIÆ .	1. Rhabdocœla .	*Mesostomum.*
		Microstomum.
	2. Dendrocœla .	*Polycelis.*
		Bipalium.
II. NEMERTINA .	1. Anopla . .	*Lineus.*
		Nemertes.
	2. Enopla .	*Borlasia.*
		Prorhynchus.
	***Branch* B. SUCTORIA.**	
I. TREMATOIDEA	1. Monogenea .	*Aspidogaster.*
		Polystoma.
	2. Digenea .	*Distoma.*
		Monostoma.
II. CESTOIDEA .	1. Caryophyllidea	*Caryophyllæus.*
	2. Tetraphyllidea.	*Tetrarhynchus.*
		Phyllobothrium.
	3. Diphyllidea .	*Echinobothrium.*
	4. Pseudophyllidea .	*Ligula.*
		Bothriocephalus.
	5. Cyclophyllidea	*Tænia.*

Class.		*Order.*		*Examples.*
III. Hirudinea	.	1. Pericœla	.	*Astacobdella.*
		2. Bdellidea	.	*Pontobdella. Nephelis. Hirudo.*

Classes and Orders of the APPENDICULATA.

Branch A. CHÆTOPODA.

I. Oligochæta	.	1. Naidina	.	*Nais. Chætogaster.*
		2. Sœnurina	.	*Tubifex. Enchytræus.*
		3. Lumbricina	.	*Lumbricus. Acanthodrilus.*
II. Polychœta	.	1. Vagantia	.	*Nereis. Polynoe.*
		2. Sedentaria	.	*Arenicola. Sabella.*
		3. Haliscolecina	.	*Capitella.*
Appendix a	.	Myzostoma	.	*Myzostoma.*
Appendix b	.	Archisyllidea	.	*Saccocirrus. Polygordius.*

Branch B. ROTIFERA.

Rotifera	.	1. Arthroptera	.	*Pedalion.*
		2. Chœtoptera	.	*Triarthra. Polyarthra.*
		3. Loricata	.	*Brachionus. Noteus.*
		4. Tubicola	.	*Stephanoceras. Melicerta.*
		5. Bdelligrada	.	*Hydatina. Rotifer.*
Appendix	.	Mutica	.	*Balatro. Asplachna.*

Branch C. **GNATHOPODA**, (Syn. Arthropoda).

Grade A. Malacopoda.

Class.	Order.	Examples.
I. PERIPATIDEA		*Peripatus.*

Grade B. Condylopoda.

Class.	Order.	Examples.
I. CRUSTACEA .	*Grade* A. *ENTOMOSTRACA.*	
	1. Cirrhipedia .	*Lepas.* *Peltogaster.*
	2. Copepoda .	*Cyclops.* *Lernæa.*
	3. Ostracoda .	*Cypris.* *Cypridina.*
	4. Branchiopoda .	*Daphnia.* *Apus.*
	Grade B. *MALACOSTRACA.*	
	Branch A. THORACOSTRACA.	
	1. Schizopoda .	*Mysis.* *Thysanopus.*
	2. Stomapoda .	*Squilla.*
	3. Decapoda .	*Astacus.* *Pagurus.*
	4. Cumacea .	*Diastylis.*
	Branch B. ARTHROSTRACA.	
	1. Isopoda .	*Oniscus.* *Anilocra.* *Tanais.* *Præniza.*
	2. Amphipoda .	*Gammarus.* *Hyperia.* *Cyamus.*
INSECTA II. HEXAPODA .	Grade A. *MASTICANTIA.*	
	1. Tocoptera .	*Campodea.* *Libellula.* *Phryganea.* *Termes.* *Blatta.*
	2. Coleoptera .	*Dystiscus.* *Stylops.*
	3. Hymenoptera .	*Vespa.* *Formica.*

Class.	*Order.*	*Examples.*
	Grade B.	*SUGENTIA.*
	1. Rhyncota .	*Aphis.* *Cicada.* *Nepa.* *Cimex.*
	2. Diptera .	*Musca.* *Tipula.*
	3. Lepidoptera .	*Papilio.* *Sphinx.*
INSECTA MYRIAPODA .	1. Chilognatha .	*Julus.* *Polyzonium.*
	2. Chilopoda .	*Scolopendra.* *Scutigera.*
	Branch A.	TRACHEOPULMONATA.
	1. Scorpionidea .	*Scorpio.* *Chelifer.*
	2. Pedipalpa .	*Phryne.* *Thelyphonus.*
	3. Galeodea .	*Galeodes.*
	4. Araneida .	*Mygale.* *Lycosa.*
	5. Phalangida .	*Opilio.* *Gonyleptus.*
	6. Acarina .	*Hydrachna.* *Demodex.*
ARACHNIDA .	*Branch* B.	BRANCHIOPULMONATA.
	1. Xiphosura .	*Limulus.*
	2. Eurypterina .	*Pterygotus.* *Slimonia.*
	3. Trilobitina .	*Phacops.* *Ilenus.*
	Appendix.	METARACHNÆ.
	1. Linguatulina .	*Linguatula.*
	2. Tardigrada .	*Arctiscon.* *Macrobiotus.*
	3. Pycnogonida .	*Pycnogonum.* *Phoxochilidium.*

CLASSES AND ORDERS OF THE MOLLUSCA.

Branch A. EUCEPHALA.

Class.	*Order.*	*Examples.*
	GRADE A. Lipoglossa.	
SOLECOCMORPHA	. . . . .	*Neomenia.*
	GRADE B. Echinoglossa.	
I. GASTROPODA	GRADE *a.* *AMPHOMŒA.*	
	1. Polyplacophora	*Chiton.* *Chitonellus.*
	GRADE *b.* *COCHLIDES.*	
	1. Autocochlides	*Patella.* *Buccinum.*
	2. Natantia .	*Atlanta.* *Pterotrachea.*
	3. Cryptocochlides	*Aplysia.* *Eolis.*
	4. Pulmonata .	*Limax.* *Limnæus.*
II. CEPHALOPODA	GRADE *a.* *PTEROPODA.*	
	1. Thecosoma .	*Hyalæa.* *Criseis.*
	2. Gymnosoma .	*Clio.* *Pneumodermon.*
	GRADE *b.* *SIPHONOPODA.*	
	1. Tetrabranchia .	*Orthoceras.* *Nautilus.*
	2. Dibranchia .	*Spirula.* *Loligo.*
III. SCAPHOPODA	. . . .	*Dentalium.*

Branch B. LIPOCEPHALA.

Class.	*Order.*	*Examples.*
I. TENTACULIBRANCHIA (Bryozoa)	Branch *a.* HOLOBRANCHIA.	
	Grade *a.* *Ectoprocta.*	
	1. Phylactolæma	*Lophopus.* *Plumatella.*
	2. Gymnolæma .	*Paludicella.* *Flustra.*
	Grade *b.* *Entoprocta.*	
	Pedicellinea .	*Pedicellina.* *Loxosoma.*
	Branch *b.* PTEROBRANCHIA.	
	Podostoma .	*Rhabdopleura.*

CLASSES and ORDERS of the VERTEBRATA.

Branch A. UROCHORDA.

Class.	*Order.*	*Examples.*
I. LARVALIA	. . . .	*Appendicularia.* *Kowalewskyia.*
II. SACCATA	1. Ascidiæ . .	*Ascidia.* *Clavellina.* *Botryllus.*
	2. Luciæ . .	*Pyrosoma.*
	3. Thaliacea .	*Salpa.* *Doliolum.*

Branch B. CEPHALOCHORDA.

I. LEPTOCARDIA .	. . .	*Amphioxus.*

Branch C. CRANIATA.

Grade A. Cyclostoma (Monorrhina).

I. HYPEROTRETA.	. . .	*Myxine.* *Bdellostoma.*
II. HYPEROARTIA	. . .	*Petromyzon.*

Grade B. Gnathostoma (amphirrina).

Subgrade A. *Heterodactyla branchiata.*

I. PISCES
II. DIPNOI } (See separate Lists).

Subgrade B. *Pentadactyla branchiata.*

I. AMPHIBIA (See separate List).

Subgrade C. *Pentadactyla lipobranchia.*

Branch A. Monocondyla.

I. REPTILIA
II. AVES . } (See separate Lists.)

Branch B. Amphicondyla.

I. MAMMALIA (See separate List).

Divisions of the HETERODACTYLA.

Class I.—Pisces.

Subclass.	*Order.*	*Examples.*	
Selachii	1. Squali	*Heptanchus.* *Squatina.*	
	2. Raii	*Raia.* *Torpedo.*	
Holocephali	. . .	*Chimæra.* *Callorhynchus.*	
anoidæ	1. Sturiones	*Acipenser.* *Polyodon.*	
	2. Polypterini	*Polypterus.* *Calamoicthys.*	
	3. Lepidosteini	*Lepidosteus.* *Palæoniscus.*	
	4. Amiadini	*Amia.*	
	5. Cephalaspidæ	*Cephalaspis.* *Pteraspis.*	Extinct.
	6. Placodermi	*Pterichthys.* *Coccosteus.*	Extinct.
	7. Acanthodini	*Acanthodes.* *Diplacanthus.*	Extinct.
	8. Pycnodontidæ	*Pycnodon.* *Platysomus.*	Extinct.
	9. Cælacanthini	*Cælacanthus.*	Extinct.
	10. Dipterini	*Holoptychius.* *Osteolepis.*	Extinct.
leostei	Branch A. *Physostomi.*		
	1. Abdominales	*Clupea, Salmo, Esox, Cyprinus, Silurus, Mormyrus.*	
	2. Apodes	*Muræna, Conger.* *Gymnotus.*	
	Branch B. *Physoclisti.*		
	1. Anacanthini	*Gadus.* *Pleuronectes.*	
	2. Pharyngognathi	*Belone.* *Labrus.*	
	3. Acanthopteri	*Perca, Trigla, Zeus, Cyclopterus, Lophius.*	
	Branch C. *Plectognathi.*		
	1. Plectognathi	*Ostracion.* *Diodon.*	
	Branch D. *Lophobranchi.*		
	2. Lophobranchi.	*Syngnathus.* *Hippocampus.*	

[redacted]

Class II.—Dipnoi.

Subclass.	*Order.*	*Examples.*
	1. Monopneumones.	*Ceratodus.*
	2. Dipneumones .	*Protopterus.* *Lepidosiren.*

Subclasses and Orders of the PENTADACTYLA BRANCHIATA.

I. Lissamphibia	1. Urodela .	*Proteus.* *Salamandra.*
	2. Anura .	*Rana.* *Dactylethra.*
II. Phractamphibia	1. Labyrinthodonta	*Archegosaurus.*
	2. Gymnophiona	*Cæcilia.* *Siphonops.*

Classes and Orders of the LIPOBRANCHIA MONOCONDYLA.

Class I.—Reptilia.

Subclass.	*Order.*	*Examples.*

[redacted]

Subclass.	Order.	Examples.
PTEROSAURIA	1. Rhamphorhynchia	*Rhamphorhynchus.*
	2. Pterodactyla	*Pterodactylus.*
DICYNODONTA		*Dicynodon.* *Rhynchosaurus.*
ORNITHOSCELIDA		*Megalosaurus.* *Iguanodon.* *Compsognathus.*
CROCODILIA	1. Teleosauria	*Teleosaurus.*
	2. Steneosauria	*Steneosaurus.*
	3. Alligatores	*Crocodilus.* *Gavialis.* *Alligator.*

CLASS II.—AVES.

1. Saururæ	*Archæopteryx.*
2. Ratitæ	*Struthio.* *Apteryx.*
3. Carinatæ	*Anser.* *Psittacus.*

GRADES AND ORDERS OF THE LIPOBRANCHIA AMPHICONDYLA.

CLASS MAMMALIA.

Grade A. Cloacalia.

1. Platypoda	*Ornithorhynchus.*
2. Echidnida	*Echidna.*

Grade B. Marsupialia.

1. Barypoda	*Nototherium.*
2. Macropoda	*Macropus.* *Hypsiprymnus.*
3. Rhizophaga	*Phascolomys.*
4. Carpophaga	*Phascolarctus.* *Phalangista.*
5. Cantharophaga	*Perameles.* *Myrmecobius.*
6. Edentula	*Tarsipes.*
7. Creophaga	*Dasyurus.* *Thylacinus.*
8. Pedimana	*Didelphys.* *Chironectes.*

Grade C. Placentalia.

Subclass.	*Order.*	*Examples.*
I. Edentata .	1. Bradypoda .	*Megatherium.* *Cholæpus.*
	2. Effodientia .	*Myrmecophaga.* *Manis.* *Orycteropus.* *Dasypus.*
II. Ungulata .	1. Perissodactyla.	*Equus.* *Tapirus.*
	2. Artiodactyla .	*Sus.* *Bos.*
	3. Sirenia . .	*Halicore.*
III. Proboscidea	Proboscidea. .	*Elephas.* *Dinotherium.*
IV. Chelophora.	Hyracoidea. .	*Hyrax.*
V. Carnaria .	1. Carnivora .	*Canis.* *Ursus.* *Felis.*
	2. Pinnipedia .	*Phoca.*

[redacted]

NOTES AND MEMORANDA.

Leboucq on the Development and Termination of Nerves in Larval Batrachians ('Bulletin de l'Académie Royale de Belgique,' 1876).—In this paper the author describes (1) the development of the nerves, and (2) the structure of the terminations of the non-muscular nerves.

As these researches were commenced rather late in the season it was not possible to obtain animals sufficiently young to study the first appearance of the peripheral nerves. Accordingly, the first part of the paper refers to the progressive evolution of the nerves.

The larval forms of various Bactrachians were examined, both in the fresh state and after treatment with osmic acid.

1. *Development of Nerves.*—The author considers, first, the nerve-fibres and their ramifications; secondly, the enlargements in the course of the fibres.

Nerve-fibres.—In the tails of young tadpoles, examined without any previous treatment with reagents, the nerves are recognised as filaments, whose peculiar appearance at once distinguishes them. These filaments have a tolerably definite contour, but the finer details of their structure are made out with difficulty in the fresh state. Treatment with osmic acid, however, facilitates the study of these points.

Under high powers the nerve-trunks are seen to be marked with fine striæ, which seem to show that the trunks are composed of bundles of fine fibrils. The primary bundles divide dichotomously.

Parietal Enlargements.—These are of two kinds, masses of granular protoplasm, with or without nuclei, and true nuclei. The latter are found along the course of a nerve-fibre, whereas the protoplasmic masses are generally situated at the point of bifurcation of a nerve, or where a collateral branch joins it. These masses sometimes contain nuclei, with a less granular protoplasm than that surrounding them, and may possess one or more nucleoli. In other cases nuclei cannot be seen, but their presence here is considered probable, notwithstanding. The size of these masses or corpuscles varies. They

are largest at the bifurcations of medium-sized nerves or at the junction of these with collateral branches, smallest at the points of divisions of the largest nerves, though the nuclei are, as a rule, most evident here.

Lastly, the terminal bifurcations possess corpuscles of moderate size, and some of these have peculiar characters.

Instead of a granular mass, coloured brown by osmic acid, one sees a triangular element with fine granulation, in which neither nucleus nor nucleolus can be distinguished. Osmic acid imparts a pale-brown colour to these.

The nuclear bodies in the course of the nerve-fibres or "parietal nuclei" are never found opposite the point of bifurcation or where the nerve is joined by a collateral branch. They are always distintly elliptical. Their long axis is parallel to the axis of the nerve, and measures, as a rule, from 15 to 20 mm., the short axis about 5 to 8 mm.

The substance of the nuclei is finely granular, and sometimes the extremities of the long axes of these bodies have a similar appearance. Nucleoli are seen here also.

In the course of the finest nerves and of those of a medium size are seen bodies, less regularly elliptical than the above, less granular, and without nucleoli.

As the fine nerve-ramifications divide they acquire numerous anastomoses and form plexuses. The nodal points of these plexuses are occupied by granular nucleated protoplasmic masses, quite similar to those found at the points of bifurcation.

At the points where several fibres communicate there are seen regular branched cells like multipolar ganglion cells.

Leboucq regards the embryonic nerves, *i. e.* the principal trunks, as being formed of bundles of primitive fibrils in the sense attached to them by Max Schultze. Where bundles divide they split up in such a way that the ultimate ramifications are formed by the free primitive fibrils.

The fibrils are bound together by a granular cement-substance, which is most marked at the points of bifurcation. At such a point the granular mass of protoplasm is nucleated, and represents a cellular element lying on a bundle of fibrils. From this fact he draws some deductions later on. Although he was unable to demonstrate the existence of a Schwann's sheath in bundles of a certain size, Leboucq still considers that it is probably present. He holds that Max Schultze's scheme of the structure of nerve-fibres holds good for embryonic nerves also.

The primitive fibril is the fundamental element. One nerve differs from another in the quantity of elements united

in it to form a bundle, or in the presence or absence of a Schwann's sheath and a medullary sheath.

The author believes that the parietal nuclear bodies are secondary formations, from the fact that they are not seen on the finest nerve terminations, and are surrounded with only a small zone of protoplasm. These bodies are held to play a different part in the development of the nerve from that of the corpuscles of the bifurcations, which are an earlier formation.

Hensen's statement ('Virchow's Archiv,' Bd. xxxi, p. 58) that when the nerves first appear they are exclusively formed of fibrils is denied by Leboucq, for he maintains that at the bifurcations of terminal nerves there is always to be seen a thickened mass, more or less developed, which assumes, in places, the appearnce of a stellate ganglion cell. These are the elements ("Nervenbildungszellen") which most authors, since the time of Schwann, have regarded as the starting-point in the development of nerves. Leboucq has not seen any of these cells isolated, as some authors have asserted, but always found them in more or less connection with the nerve-terminations. However, as he has not made many observations in reference to this special point, he does not discuss the origin of these cells further.

Turning now to the development of the nerves, the author suggests that the embryonic cells found at the points of bifurcation may themselves give rise to the primitive fibrils, just as, according to Max Schultze and Boll, the connective-tissue fibrils are developed from the protoplasm of the connective-tissue corpuscles. According to Leboucq, these special cells are, in the first instance, non-nucleated masses of protoplasm. The activity of the protoplasm shows itself, on the one hand, in the formation of fibrils; on the other, in the development of a nucleus. This subsequent appearance of a nucleus in these "Nervenbildungszellen" has been recently described by Calberla ('Archiv f. Mikros. Anat.,' Bd. xv, p. 455). Leboucq cannot state definitely whether the other nuclei which are found on the nerve-fibres ("parietal nuclei") are also derived from the embryonic cells, though he considers it probable. He assigns to these parietal nuclei a separate rôle in the subsequent development of the medullary sheath.

Formation of the Medullary Sheath.—Certain bundles of fibrils (axis cylinders), which have been developed in the manner already mentioned, now undergo a peculiar transformation, and become invested with a medullary sheath. The period at which this occurs varies widely. But the

peculiar appearance of the nerve-medulla is easily recognised without the action of any reagent. However, the characteristic brownish-black colour given to it by osmic acid distinguishes it with great precision.

At certain points in the course of the nerve are seen areas, more deeply stained by osmic acid than the rest of the nerve. The parietal nuclei are always seated at the centre of this deeply-stained substance, as if this were deposited around the nuclei. Here we have the commencing formation of nerve-medulla, which appears on the bundle of fibrils in the shape of interrupted masses, the interruptions corresponding to the intervals between two nuclei.

The effect of this process in a medullated nerve-fibre that has reached a certain stage of development is very remarkable. The nerve-medulla is deposited on a bundle in such a way as to form segments, which are more or less regular and limited on both sides by a point where the medulla is wanting (a constriction of Ranvier).

Towards the middle of each segment is seen a nucleus. At this stage, then, the embryonic nerves show the characters described by Ranvier, Axel Key, and Retzius. The author finds that, at the level of each constriction a principal trunk gives off a collateral branch, which also behaves in a similar way.

When these researches were being made this peculiarity had not been described by other workers in the same field, but a little later Rouget also drew attention to this fact in a memoir on the development of nerves ('Archiv. de Phys.,' Feb., 1876).

A bundle of fibrils seldom becomes medullated throughout its whole circumference. As a rule, some portions at the side of a bundle of medullated fibres preserve their embryonic character. This fact, first noticed by Rouget, is explained by him as follows:

"The multiplication of nerve-fibres consists in a process of cleavage. The nucleus divides in the direction of its long diameter, and simultaneously the whole fibre splits longitudinally into two.

"In a system of two fibres united together, one undergoes a progressive development, becoming medullated, while the other, preserving its embryonic character, persists as a pale fibre, and provides for the multiplication of the nerve-fibres."

Leboucq considers, however, that the fact that collateral branches arise from the medullated fibres at the level of the constrictions of Ranvier shows that these same medullated

fibres can themselves aid in the multiplication of nerve-fibres.

According to Ranvier the constrictions are the points of greatest nutritive activity in the medullated fibres. It is probable, therefore, in the case of embryonic nerves, that these are also the points where the greatest amount of formative energy is manifested.

The deposit of nerve-medulla does not always proceed with the same regularity in all fibres. As a rule, the length of the segments decreases gradually from their origin to their peripheral termination. Sometimes the medulla is developed on alternate segments, leaving out the intermediate portions.

Summing up his views on the formation of the medullary sheath, Leboucq concludes this portion of his memoir in the following statements :

The parietal nuclei are derivatives of the embryonic cells, and are found in the substance of protoplasmic masses or plates surrounding the bundles of fibrils. These nucleated masses correspond to the "Häutchenzellen" of Axel Key and Retzius.

Each nucleus corresponds to a special area of the sheath of one bundle of fibres.

Each protoplasmic cell-mass ("Häutchenzelle") corresponds to one segment of medulla, the limit between two neighbouring cells constituting a constriction.

The nerve-medulla is developed by a chemical metamorphosis of the elements surrounding a bundle of fibrils, not, as Köllker holds, by a transformation of the peripheral fibrils of a bundle.

The Peripheral Nerve Terminations.—This division of the paper commences with a preliminary account of the structure of the epithelial covering of the skin of the animals examined. Attention is drawn to a peculiar form of cement-substance between these epithelial cells. This cement-substance has a peculiar dotted appearance, like a "row of pearls."

Leboucq next proceeds to describe two kinds of cells found in the deeper layer of the epithelial covering of the skin, corresponding to the human rete Malpighii. These cells are believed to be in connection with the nerve endings. The first sort are finely granular, branched corpuscles, about 3 to 6 mm. in breadth and 25 to 30 mm. in length. These corpuscles, which are placed between the epithelial cells, are coloured by osmic acid, like nerves, but show neither nucleus nor nucleolus.

The processes of these corpuscles can almost always be seen to be in connection with nerve fibrils, sometimes with fairly

large fibres.[1] This fact excludes the possibility of their being connective-tissue corpuscles, from which they are in other respects also quite different. Cells like these have been described by various authors, *e.g.* by Kölliker, in the deeper layers of the epidermis of the mouse; by Tomsa, in human skin; by Langerhaus, in human skin after treatment with chloride of gold; by Kisselew, in the vesical epithelium; by Poncet, in the conjunctival epithelium of the ox.

The other sort of cell, which is believed to be in connection with nerve endings, is larger, coarsely granular, and rounded, with a nucleus that is stained a deep brown by osmic acid. These cells closely resemble the "Schleimzellen" described by Leydig.

The author does not speak positively of the connection of these cells with nerve-fibres, and, indeed, his drawings do not seem perfectly conclusive. He believes that a fine nerve-fibril enters one of these granular cells and runs up to the nucleus, where it disappears in the granular cell-substance. In one of his drawings such a connection is only apparent, as he is himself somewhat inclined to admit. Leboucq considers these cells to be quite analogous to those described by Langerhaus in "*Petromyzon Planeri*," and to those which the same author more recently figured, among the ordinary epithelial cells of the Amphioxus, as tactile corpuscles—"Fühlzellen" ('Archiv f. Mikros. Anat.,' Bd. xii, Heft 2).

The paper concludes with the following short *résumé:*

1. The embryonic nerve is composed of a bundle of primitive fibrils, developed out of the protoplasm of the embryonic cells, or "Nervenbildungszellen."

2. The derivatives of these formative cells, which surround a bundle of primitive fibrils (an axis cylinder), form the medullary sheath by a special metamorphosis. Each derivative of an embryonic cell provides for the development of one segment of medulla; the point of contact of two neighbouring cells forms a constriction of Ranvier.

2. The terminal plexuses of nerve-fibres are in connection with special corpuscles situated between the deeper epithelial cells, the cement-substance here showing the same characters as that described by Ranvier in the human rete Malpighii.

4. Certain granular cells placed between the epithelial elements seem also to be in connection with nerve-endings.

[1] I have described a similar connection of the terminal nerve fibres in the tail of the tadpole, with branched corpuscles which appear to be situated beneath the epithelium. The terminal network of nerve-fibres which I found in this locality is of far greater richness than that seen by M. Leboucq.—E. KLEIN.

PROCEEDINGS OF SOCIETIES.

Dublin Microscopical Club.

15*th March*, 1877.

Ravenelia stictita exhibited.—Mr. Pim showed *Ravenelia stictica*, an East Indian fungus, which he had received from Rev. J. E. Vize, to whom it had been sent by Col. Hobson. The genus Ravenelia belongs to the Uredinei; it consists of several cells united together resembling somewhat the genus Urocystis; they are beset with remarkable prominences reminding one of the zygospores of some Desmidieæ. Mr. Pim was unable to ascertain on what plant this fungus was parasitic; it mostly affects Leguminosæ; one or two species have been found in North America.

A new Coscinodiscus (collected by Mr. Moseley, H.M.S. 'Challenger'), from the Sea of Arefusa.—Rev. E. O'Meara presented a number of Diatomaceous forms from a gathering made from the surface of the Sea of Arefusa by Mr. Mosely, of H.M.S. 'Challenger.' Mr. O'Meara characterised this as one of the richest collections that had ever come under his notice. Numerous species of Rhizosolenia, Chætoceros, Bacteriastrum, &c., occurred in ample abundance. To one form Mr. O'Meara called special attention —a large species of *Coscinodiscus*—which he considered undescribed. At first view it might appear rather to belong to the genus Craspedodiscus, but, on more minute examination, the apparently distinct border disappeared. The following is a description of the species: Diameter ·022", centre large, free from areolation. Areoles radiate, at the margin large, hexagonal, thence somewhat compressed, decreasing in size towards the centre, and somewhat elongated. Towards the end of the radiate lines of areoles are somewhat shorter than others, in consequence of which the free centre has somewhat of a starlike appearance. He proposed to name this form *Coscinodiscus Craspedodiscus.*

Petalonema alatum, Berkeley, *from Falls of Niagara, exhibited.* —Dr. Barker showed examples of the alga, *Petalonema alatum*, taken by him at the Falls of Niagara; these appeared in every way similar to the British.

Sagitta tricirrhata, Saville Kent, *exhibited.*—Dr. Macalister exhibited specimens of *Sagitta tricirrhata*, Saville Kent, sent him

by Captain Chimmo from the Sulu sea. The various structural points of Sagitta were easily distinguished, and the striped muscular fibre formed a high-power object of great beauty.

A probably new Species of Sagitta exhibited.—Dr. Macalister exhibited a specimen of Sagitta, obtained from the Godefroy Museum in Hamburg, and supposed to have come from the South Seas; it was over 3 cm. in length with an elongated marginal fin; no seminal vesicles or long surface bristles. The head bristles were six on the left side and three on the right. The jaws had three terminal spines and lateral saw-like teeth. The nervous system exhibited only two lateral branches from the ventral ganglion instead of the numerous little ramuli figured by Professor Huxley. The specimen came nearest to *S. Lyra*, but did not exhibit the caudal groove, and differed in the numbers of denticles from that species as described by Krohn.

On the Structure of the Leaf of Erythroxylon Coca, L.—Professor McNab exhibited preparations of the leaf of the Coca plant, *Erythroxylon coca*, L. The epidermis of the under side of the leaf bears a number of very minute stomata. These stomata measure about $\frac{1}{1500}''$ in length by $\frac{1}{2000}''$ in diameter. The air-spaces are themselves about $\frac{1}{300}''$ to $\frac{1}{1000}''$ across. The transverse section of the leaf shows the epidermis of the upper side, then a single row of palisade parenchyma, then the loose cellular tissue (somewhat resembling the air-cells of the lung) with large intercellular spaces, and lastly, the epidermis of the under side with stomata. The midrib is strongly marked, and projects considerably, thus contrasting with the thin laminæ. Above the midrib, in the middle line of the leaf, is a small longitudinal keel. On the inner side of the leaf, on each side of the midrib, is a similar raised longitudinal keel. These longitudinal keels have been mistaken by Sir Robert Christison and other observers for lateral veins. A careful examination showed that the keel consisted of epidermis and ground tissue merely, no fibro-vascular bands running in it from base to apex of the leaf. Baillon seems to be right in explaining the formation of the keel as due to the mode of folding the leaves in the bud.

Myxastrum-form, probably a new species, exhibited.—Professor E. Perceval Wright exhibited specimens of what he took to be a species of Häckel's genus Myxastrum. These approached somewhat to the only described species *M. radians*, found at the Canary Islands, but still seemed in certain respects to differ therefrom. This form occurred not unfrequently in bottles in which marine algæ collected at Howth had been kept for some time in a growing condition. The little dark-brown patches which clung to the side of the glass next the light could be just seen with unassisted vision, and with them were associated Diatoms, Glœocapsa-cells, and such like. The individual portions resembled minute Actinophryans; at certain times the "fluffy" nature of the pseudopodia seemed to pass over into a more or less regular series of rays; at other times the ray-like portions were lost and the form

became encysted; and again, the ray-like portions seemed to aggregate together like what is seen in Myxodictyum.

18*th April*, 1877.

Preparations of monstrous form of Muscari exhibited.—Mr. G. Pim showed some preparations of *Muscari comosum*, var. *monstrosum*, in which all the floral organs were converted into long filiform bodies, beset with small protuberances, probably buds, and consisting of one or two plates of parenchymatous tissue. This form is permanently monstrous.

Olpidium (Chytridium) *tumefaciens*, Magnus, *exhibited.*—Professor E. Perceval Wright showed a series of specimens of *Olpidium* (Chytridium) *tumefaciens*, P. Magnus, found living in the trichomes and young cells of the thallus of *Ceramium acanthonotum*, collected at Howth. The species had been described by Professor Magnus in the 'Jahresbericht der Commission zur wissenschaftlichen Untersuchung der Deutschen Meere in Kiel,' p. 76, t. i, f. 1—16. The algæ with this parasite were found by Professor Magnus at Fisherrow, near Edinburgh. It was not uncommon at Howth. *Chytridium Sphacellarum*, Kny, though not exhibited, had also been met with.

New Species of Coscinodiscus shown.—Rev. E. O'Meara exhibited what appeared to him to be an undescribed species of Coscinodiscus found by him in the remarkable gathering by Mr. Moseley, H.M.S. "Challenger," from the surface of the Arefusa Sea. The form is large, diam. 0·015", however, considerably smaller than the very striking species exhibited at last meeting by Mr. O'Meara under the name of *Coscinodiscus craspedodiscus*, a comparison with the leading features of which would best pourtray the characteristics of the present. Here the broad margin so remarkable in the former is absent. In the present form, as in it, the radiate lines of areoles terminate some distance from the centre; the central blank space, however, is much smaller, and the lines of areoles are of more equal length. Areoles of margin subhexagonal, diminishing in size towards the ends; they are shorter, broader, and much more robust than in *Coscin. craspedodiscus*. Mr. O'Meara proposed to name the species from the locality where it had been found—*Coscinodiscus Arafusænsis*.

Section of Spine of Echinothrix annellata, Peters, *exhibited.*—Mr. Mackintosh exhibited a cross section of the spine of *Echinothrix annellata*, Peters, specimens of which had been kindly sent him by Dr. Günther, F.R.S. This species had been united with *E. Desorii*, Peters, by Prof. A. Agassiz in his recent "Revision of the Echinoderms," but it differs, as far as can be judged, from the present specimens in the total absence of the reticular tissue, which is so conspicuous a feature in the spine of *E. Desorii*, and in the extremely slender nature of the solid wedges (scarcely deserving the name of wedges), their circumferential being hardly thicker than their central parts.

A new Species of Staurastrum shown.—Mr. Archer showed, amongst other forms, a new species of Staurastrum, generally very rare as yet, though not uncommon in Callary bog. The only other place it had occurred was sparingly in Connemara. It somewhat resembled *St. oligacanthum*, Bréb., but the little tufts of spinelets at the slightly prolonged angles and on upper margin would quite readily distinguish it. He would reserve a description. The Connemara and Callary forms were absolutely identical.

Macrospores of Salvinia natans exhibited.—Dr. E. Perceval Wright exhibited germinating macrospores of *Salvinia natans*, which were the produce of plants collected in September, 1876, in the Spree by Prof. E. von Martens, and kindly forwarded to Dr. Wright to Köln. The macrospores began to float to the surface of the water in the last week of March, and at once developed their three-edged emerald green prothallium; only within the last few days (15th April) did the microspores arrive at the surface, but speedily under the influence of a few days of bright sunlight did their spherical cells develope the antherozoids. Just as mentioned by Hofmeister and Pringsheim did the unfertilised archigoma turn brown, those more lately formed and fertilised beginning to form the curious scutiform leaf. Some little care and a peculiar arrangement of the light was found necessary to bring the spring plants, of which there was a numerous colony, to this stage, but should these plants produce in autumn their fruits, then the experiment of cultivating this interesting Rhizocarp may be regarded as successfully accomplished.

Amphizonella violacea, Greeff, *exhibited.*—Mr. Archer presented examples in the living state, as well as some time under Beale's fluid, of *Amphizonella violacea*, Greeff, and drew attention to the nucleus so readily to be detected. The strongly developed nuclear-membrane and the coarsely granular nature of the "contents" reminded one, Mr. Archer thought, of the nucleus in Foraminifera, as figured by Schulze. It is worthy of mention that at no time could Mr. Archer detect examples of this Sarcodine showing the smooth-surfaced, sharply bounded envelope depicted by Greeff, but this portion of the structure always showed a hazy or "fuzzy" outline, nor could he ever see the emission of finger-like pseudopodia, but only hemispherical prominences, which nowhere seemed to protrude through the outer envelope.

Hyalosphenia-form, probably Hyalosphenia (Difflugia) *ligata*, Tatem, *exhibited.*—Mr. Archer further presented a single example of a Hyalosphenia-form. To which of the two (or three?) named forms this might be relegated, from want of figures of one, Mr. Archer felt in doubt. It best agreed with Tatem's figure of his *Difflugia ligata*, in Mr. Archer's opinion better called *Hyalosphenia ligata* (if that be not equivalent to Stein's form), but it was just one half the size recorded by the former observer, or say $\frac{1}{500}''$ in length.

24*th May*, 1877.

Characters of Craspedodiscus elegans.—Rev. E. O'Meara exhibited a fine specimen of *Craspedodiscus elegans*, Ehr., from the Maryland deposit. He remarked that in Ralfs' description of this species (Pritch. Inf., Pl. XI, f. 38) the central rosette of elongated areoles and the large rhombic areoles of the broad border are accurately described, but that the central portion of the disc, instead of being turbid, as in the figure referred to, is perfectly pellucid, and the areoles, instead of being fine and granular, are large and distinctly hexagonal.

Arcyria punicea (Capillitium) exhibited.—Mr. Pim showed a portion of the capillitium of *Arcyria punicea* from Vale of Avoca. He had met with rather plentifully an allied, but distinct, form *A. incarnata* in Powerscourt Demesne. The habitat is similar, viz. rotten sticks.

Section of Tip of Spine of Arbacia stellata exhibited.—Mr. Mackintosh exhibited a cross section of the tip of the spine of *Arbacia stellata*, Gray, and called attention to the structure of the sheath which covers the tip of the spine in every species of the genus. It was apparently identical in structure with the crust of the spines of Cidaridæ, and seemed to present the link between this family and the Desmosticha, in which the sheath is not found.

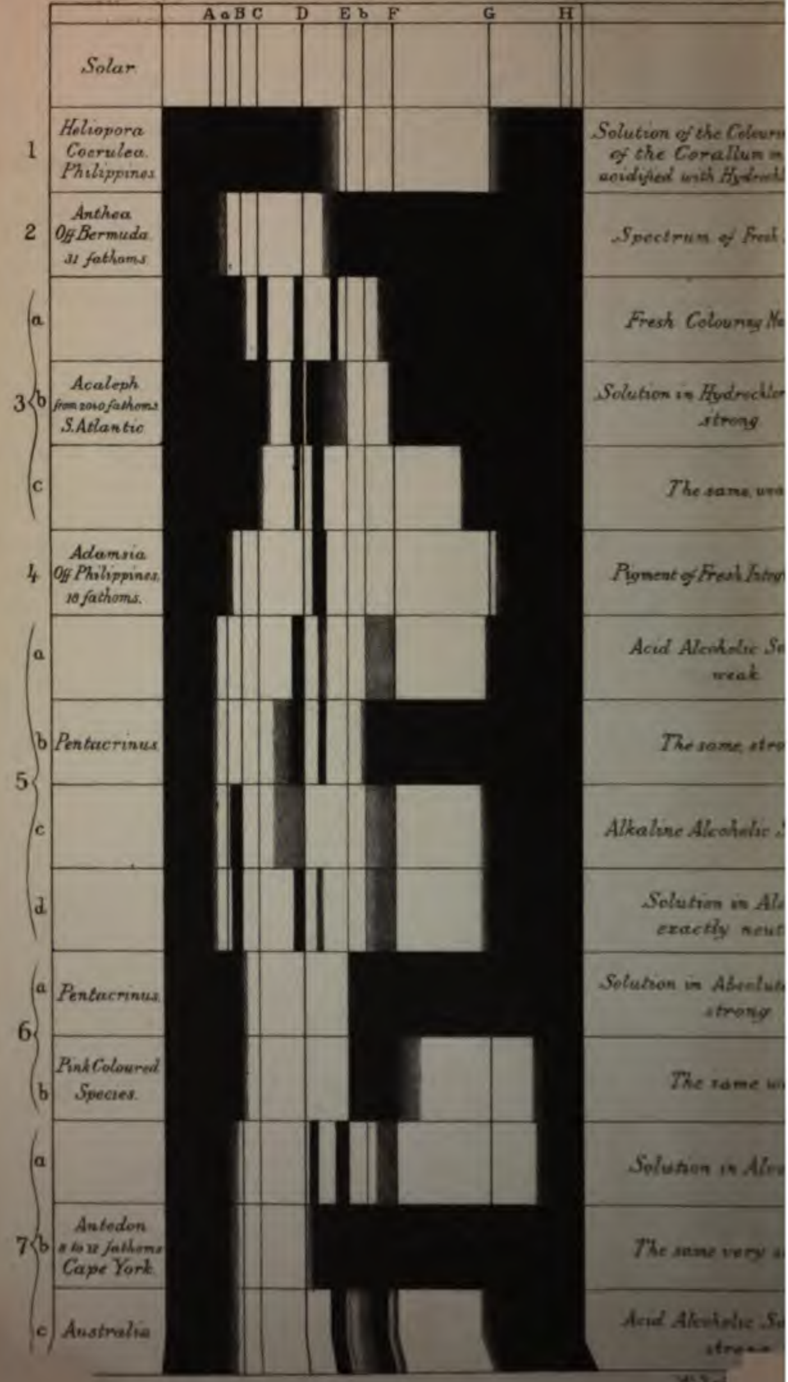
Microgromia mucicola shown in the recent state.—Mr. Archer showed the little, probably the most minute, perfect rhizopod known, nestling in the mucus of his *quondam Dictyosphærium constrictum*, viz. *Microgromia mucicola*. It would be hardly possible, so inert is this form, to demonstrate at a meeting that it was a thing of life at all, yet positively exerting all the activity of which it is capable. It would almost require the use of a micrometer eyepiece to note the action of the pseudopodia. The nucleus could readily be made out. Although Mr. Archer had already recorded this form in the Minutes, he had not had an opportunity before to show a living recent example at a Club meeting.

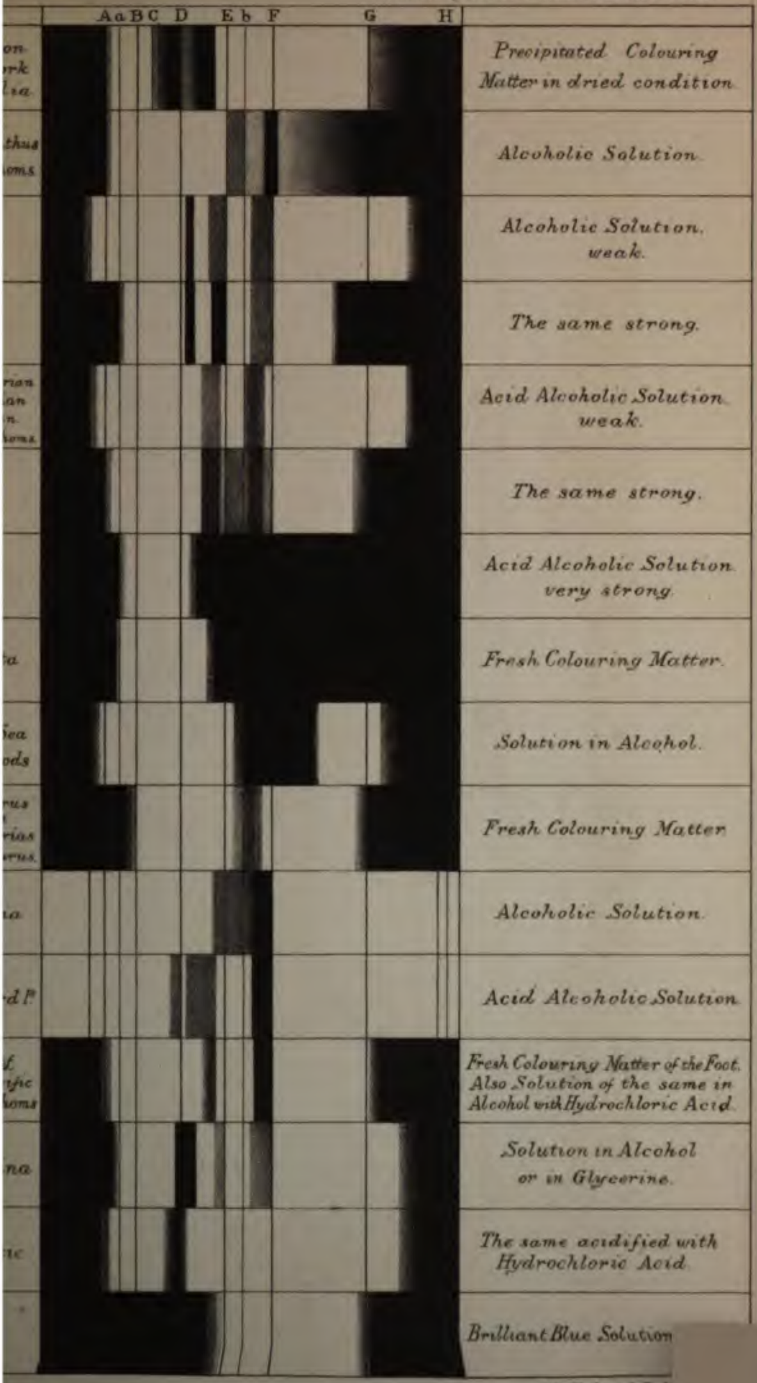
Ectocarpus sphærophorus exhibited.—Dr. E. Perceval Wright exhibited freshly gathered specimens of *Ectocarpus sphærophorus*, Carm., a species found in Bantry Bay by Miss Hutchins, and certainly not very common in Ireland. Harvey describes the spores as "opposite to each other or to a ramulus, each spore in fact occupying the normal position of a ramulus, and substituted for one on fertile specimens." Agardh better describes them as "intra-perisporium hyalinum ad fila sessiles, oppositæ aut 4-verticellatæ nunc singulæ ramulo oppositæ." Both authors apparently mean by "spores" "spore-cells," and Dr. Wright hazarded the suggestion that these hyaline spore-cases in this species were only parasitic forms, and that the *Ec. sphærophorus*, Carm., was after all but the *Ec. brachiatus*, Agardh, only under altered circumstances, and that it would then belong to the group of Ectocarpi with fruits as in *Ectocarpus Mertensii*.

Salicylate of Morphia exhibited.—Dr. Tichborne then exhibited

a slide of salicylate of morphia under the polariscope. He had prepared this salt with a number of other salicylates of the alkaloids, with a view that as they were in themselves antiseptic, solutions of these salts might be used with advantage in the practice of medicine. The morphia-salt was extremely insoluble, and when first formed was a colloid and amorphous precipitate. It, however, gradually became crystalline, particularly if heated for a short time in its own melting liquors. He had brought this salt before the Club because it was quite new and presented some peculiarities. It would be observed that in many of the crystals the faces were curved in a similar manner to the shape assumed sometimes by the faces of the diamond and other well known crystals. In fact, the salicylate of morphia crystal assumed the well-known curvilinear appearance seen in the crystals of uric acid. He was of opinion that such curvature of the face of any crystal was always indicative of the substance having originally been in the amorphous state.

[illegible]


A a B C D E b F G H
Solar
1 Heliopora Coerulea. Philippines
Solution of the Colour
of the Corallum
acidified with Hydrochl
2 Anthea Off Bermuda 31 fathoms
Spectrum of Fresh
3 a
Fresh Colouring M
b Acaleph from 2010 fathoms S.Atlantic
Solution in Hydrochlor
strong
c
The same, wea
4 Adamsia Off Philippines, 18 fathoms.
Pigment of Fresh Integ
5 a
Acid Alcoholic S
weak
b Pentacrinus
The same, stro
c
Alkaline Alcoholic
d
Solution in Al
exactly neut
6 a Pentacrinus
Solution in Absolut
strong
b Pink Coloured Species.
The same w
7 a
Solution in Alc
b Antedon 8 to 12 fathoms Cape York.
The same very
c Australia
Acid Alcoholic S
strong


A a B C D E b F G H
Precipitated Colouring Matter in dried condition
Alcoholic Solution
Alcoholic Solution. weak.
The same strong.
Acid Alcoholic Solution weak.
The same strong.
Acid Alcoholic Solution very strong.
Fresh Colouring Matter.
Solution in Alcohol.
Fresh Colouring Matter
Alcoholic Solution
Acid Alcoholic Solution
Fresh Colouring Matter of the Foot. Also Solution of the same in Alcohol with Hydrochloric Acid.
Solution in Alcohol or in Glycerine.
The same acidified with Hydrochloric Acid
Brilliant Blue Solution

CRIPTION OF PLATE III,

Moseley's paper on Stylochus Pelagicus, ies of Pelagic Planarian, with Notes on : Species, on the Larval Forms of Thysano- a Gymnosomatous Pteropod.

anarian, Thysanozoon? Magnified 60 diameters.
earlier stage. Magnified 50 diameters.
ing cilia, from the body processes of the same seen in eter of the cell ·02 mm.
of the epidermis of the same larva. Magnified 500 he arrangement of the pigmented cells, rod cells, &c.
taining oily spherules from the body mass of the same

of the same, with the rods packed so as to form a e it. Magnified 800 diameters.
d ·015 mm. in actual length.
rod seen in optical transverse section.
Pelagicus. The entire animal viewed from the under ed light. Magnified 9 diameters. General view to t of the digestive nervous and reproductive systems, ions of the generative and digestive orifices. Drawn læ.
s Pelagicus. Sketch to show the arrangement of the cephalic ganglia. The spots are placed symmetrically tches anterior and posterior, and in two rings one ch tentacle.
s Pelagicus. Generative organs much enlarged, and t schematically.
arynx. Ph. Pharynx. O. Ovary. A. G. Albumini- . U. Muscular wall of the uterus. F. G. Femalie erture. T. Testis. V. D. Vas deferens. V. S. Vesi- s. Pt. Prostate. S. P. Sheath of penis. C. P. s. M. G. Male generative aperture. R. M. Retractor es of the penis.
planarian sp.? as viewed from below by transmitted diameters to show the relative positions of parts.
. mouth. The ultimate ramifications of the digestive wn only at the fore and hinder part of the animal.
glia of the same animal magnified with the ramifications em in immediate relation with them and the eye spots. ers.
d larva. View of the larva from the dorsal surface. ters.
M. Retractor muscles of buccal mass. Œ. Œsopha- ra-œsophageal ganglion. G'. Infra-œsophageal gang- tolith. D. Digestive tract. A. Large transparent ling the upper part of the digestive tract.
the anterior part of the same larva from the ventral

. B. Buccal mass and muscles. L. Foot. L''. Ap- oot. Zipfelförmige Anhang of Gegenbaur. O. Oto- us.
erse section (optical) of the same larva in the region of e digestive tract.
D. Digestive tract. A. Large cells.

EXPLANATION OF PLATE IV,

Illustrating Mr. Peck's memoir on the Structure of the Lamellibranch's Gill.

The letters in all the figures have the following signification.

fol. Filament of the outer lamella.
fil. Filament of the inner lamella; the two being the descending and ascending "limbs" of one and the same primitive filament.
cj. Ciliated (interfilamentar) junctions.
ep. Epithelial prominences which carry the cilia of the ciliated junctions.
ilj. Interlamellar junctions (subfilamentar outgrowths or excrescences which stretch across the interlamellar space, and unite the descending and ascending limbs of a primitive filament).
e. Epithelium.
le. Lateral epithelium.
fe. Frontal epithelium.
lfe'. Latero-frontal epithelium with long cilia.
lfe''. Second row of the same.
lfc. Latero-frontal cilia.
bc. Blood corpuscle.
lac. "Lacunar" or "primitive mesoblastic" tissue (Gallertgewebe or mucous tissue).
ch. Chitinous layer (mesoblastic).
sep. Septum formed by lacunar tissue.
cav. Cavity of the filament.
lat. Broad side of the filament.

Fig. 1.—A part of three gill-filaments of Arca, seen from the surface of the lamella, showing large ciliated junctions, and focussed so as to give a median optical section. Obj. 8, oc. 4, Hartnack.

Fig. 2.—Transverse section of a gill-filament of Arca, showing epithelium, chitin, cavity, and septum. Obj. 8, oc. 4, Hartnack.

Fig. 3.—A gill-filament, twisted so as to show its narrow and broad sides, and general band-like form. Obj. 8, oc. 4, Hartnack.

Fig. 4.—Four gill-filaments of Mytilus, seen from the surface of the lamella, and focussed so as to bring the ciliated junctions into view. Obj. 4, oc. 4, Hartnack.

Fig. 5.—Three views at different focus-depths of a bit of a gill-filament of Mytilus. The left-hand figure gives the most superficial view; the middle, an optical longitudinal section through the narrowest part of the cavity of the filament; the right-hand figure, such a section through the widest part of the same cavity. The surface epithelium in this last figure should be provided with short cilia. Obj. 8, oc. 4, Hartnack.

EXPLANATION OF PLATE IV—*continued.*

Fig. 6.—Transverse section of four gill-filaments of Mytilus, as seen in a transverse section of the two lamellæ of a gill-plate. The section cuts two filaments of one lamella (the upper in the figure) *through* the area of their ciliated junctions; the lower filaments are cut *between* the position occupied by ciliated junctions. Obj. 8, oc. 4, Hartnack.

Fig. 7.—A similar transverse section to that of fig. 6, but taken across the region of interlamellar junctions. The interlamellar junctions are in this case short; they are seen to be due to simple outgrowth of the deep face of the filaments accompanied by concrescence. Obj. 8, oc. 4, Hartnack.

Fig. 8.—Portion of the descending and ascending limbs of a gill-filament of Mytilus (filaments of the outer and of the inner lamella), seen in the vertical plane at right angles to the surface of the lamellæ, and showing two interlamellar junctions in a state of contraction, and three pairs of epithelial prominences of the ciliated junctions. Obj. 4, oc. 4, Hartnack.

Fig. 9.—A bellows-like interlamellar junction in a state of partial extension, from tne gill of Mytilus. Obj. 8, oc. 4, Hartnack.

Fig. 10.—Diagram of a single gill-filament, with descending and ascending limb (filament of the inner and of the outer lamellæ), from the left outer gill-plate of *Mytilus edulis*. The diagram shows the grooved apex or angle of the gill-plate, the hook-like termination of the free limb of the filament, the position and number of the ciliated junctions (epithelial prominences) and of the interlamellar junctions. The relative breadth of the filament, as compared to its length, is exaggerated to the extent of about twice the actual proportion.

EXPLANATION OF PLATES V, VI, & VII,

Illustrating Mr. Peck's memoir on the Structure of the Lamellibranch's Gill.

The letters in all the figures have the same signification.

Larger Parts.

O L. Outer lamella.
I L. Inner lamella.
ilj. Interlamellar junction.
F. Gill-filament (not in figure 18, see below).
ils. Interlamellar space.
Tr. Transverse elements, or interfilamentar junctions.
sfe. (In fig. 17) Surface of the subfilamentar outgrowth or internal surface of the lamella.
V. Large vertical vessel.
v'. Small horizontal or transverse vessel.
W. Window or stoma of a water-passage.
o s. Outer surface of a section.
e s. Inner surface of a section.
l. Lumen of a vessel.

Histological Detail.

e. Epithelium.
f e. Frontal epithelium of the gill-filaments.
lfe, lfe', lfe''. Latero-frontal epithelium of the first or second order (gill-filament).
le, le'. Lateral epithelium of the gill-filaments.
lac. Lacunar tissue (primitive mesoblastic or mucous tissue).
ch. Chitinous deposit representing part of the chitinous tube of the primitive Lamellibranch gill-filament.
chc and nch. Corpuscles embedded in the above chitinous deposit.
cr. Chitinous rods differentiated in the chitinous deposit (*ch*).
tr f. Fibrous tissue of the transverse interfilamentar junctions.
bc. Blood-corpuscle.
yg. Yellow granular material accumulated in the subfilamentar lacunar tissue of Anodon, and destined for the nutrition of the Glochidian embryos.
pig. Pigmented corpuscles of the lacunar tissue.
ff. Elastic or muscular fibrous elements in the lacunar tissue.
f. (In fig. 18) Trabecula of the lacunar tissue.
n. Nucleus surrounded by granular protoplasm (lacunar tissue).
pe. Peripheral expansion and attachment of a trabecula.

PLATE V.—Anodon.

Fig. 1.—Transverse section of a portion of an outer gill-plate, with swollen lacuna-bearing interlamellar junctions. Low power.

Fig. 2.—Transverse section of a portion of an outer gill-plate, with solid interlamellar junctions and large vertical vessels. Low power.

Fig. 3. Transverse section of a portion of an *inner* gill-plate, showing curvature of the outer lamella, relatively small depth of inner lamella and vertical vessels in the inter-lamellar junctions. Low power.

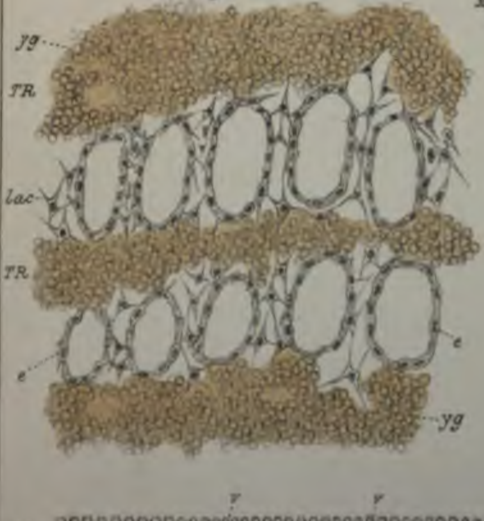
Fig. 4. Transverse section of a portion of outer gill-plate, distended with Glochidian embryos (schematic).

3

Pl. VI

Fig. 14.

Fig. 15.



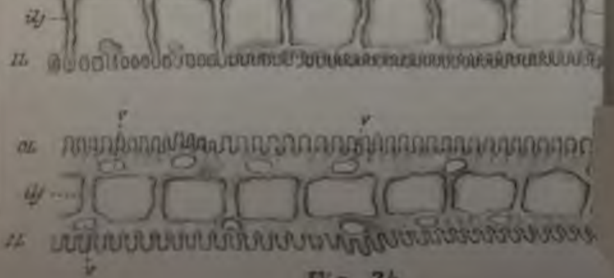


Fig. 24.

EXPLANATION OF PLATE V—*continued.*

Fig. 5. Fragment of the outer lamella of an *inner* gill-plate, showing two interlamellar junctions, stomata of the water-passages and gill-filaments here and there exposed by tearing off the subfilamentar tissue. Seen from the deep or interlamellar surface with a hand lens (from a drawing by Mr. Lankester).

Fig. 6.—Tranverse section of a portion of an outer gill-plate taken near the apex or free angle (see Plate IV, fig. 10). The interlamellar concrescence is not limited as in sections across the middle level of the gill, to definitely disposed interlamellar junctions. Low power.

Fig. 7.—Transverse section of a portion of an outer gill-plate, still nearer to the angle of the plate. The regular concrescence on the right-hand side of the section is noteworthy. The section, though at right angles to the filaments, approaches on this side nearer to the angle of the gill-plate than it does on the left-hand side. Low power.

Fig. 8.—Diagrammatic view of a block cut from the outer lamella of the outer gill-plate when not functioning as a brood-pouch, seen from the interlamellar surface. This figure shows the relation of the water-passages and their stomata to the interfilamentar spaces, and is intended to render the transverse sections given in other figures intelligible (from a drawing by Mr. Lankester).

Fig. 9.—Highly magnified view of a portion of such a section as that given in fig. 2.

Fig. 10.—A similarly magnified view of a portion of fig. 1.

Fig. 11.—A similarly magnified view of a portion of fig. 3.

Fig. 12 —A transverse section of a single filament taken *between* the horizons of transverse interfilamentar junction, and at a point where the subfilamentar outgrowth is least prominent or developed. Obj. 8, oc. 4.

Fig. 13.—Transverse section through two filaments and subjacent subfilamentar tissue taken *at* the horizon of a transverse interfilamentar junction. The reduction of the chitinous rods, the continuity of the chitinous deposit with the transverse fibres and the character of the subfilamentar lacunar tissue, are well seen.

PLATE VI.—Anodon (except fig. 24, 30, and 31).

Fig. 14.—Longitudinal section parallel with the surface of the lamella and passing through the horizon of the chitinous rods. The external stomata of the water-passages, the transverse and the *obliquely-crossing* elements of the fibrous interfilamentar junctions are shown, as well as the continuity of the chitinous rods.

Fig. 15.—A similar section taken more deeply, so as to lie in the horizon of the subfilamentar mass of lacunar tissue which grows out from the deep surface of the filaments. It shows the lumina of the water-passages in section and the lacunar tissue with its spaces blocked to some extent by yellow granular food-material destined for the Glochidian embryos.

Fig. 16.—A more highly magnified view of a similar section taken somewhat deeper (near the interlamellar or subfilamentar surface of the lamella), and thick enough to show the tapering of the water-passages towards their interlamellar openings, windows, or stomata.

Fig. 17.—Diagram of a block of the inner lamella of the outer gill-plate, cut vertically through an interfilamentar region, and exposing the interior of three water-passages. The forward position of the fibrous interfilamentar junctions (*trf.*) is seen, and the great depth and bulk of the mass of concreted subfilamentar tissue rendered obvious. (From a drawing by Mr. Lankester.)

Fig. 18.—A fragment of a subfilamentar outgrowth in section, to

show the trabeculæ of the lacunar tissue and their nuclei. This and fig. 20 are drawn to a larger scale than any of the other sections.

Fig. 19.—Section of a fragment of subfilamentar lacunar tissue, to show the nature of the wall of one of the large vertical vessels. A small horizontal trunk is seen connected with it. Compare fig. 11.

Fig. 20.—Diagram of a gill-filament seen from the supra-lamellar surface, and cut so as to show (1) the surface epithelium, (2) the higher lateral epithelium, and (3) the deeper lateral epithelium. The diagram is constructed from optical sections (from a drawing by Mr. Lankester).

Fig. 21.—The large cells of the latero-frontal epithelium; three as seen from the supra-lamellar surface; one in the plane at right angles to this.

Fig. 22.—Epithelium from the gill-filament.

Fig. 23.—Epithelium of the supra-lamellar surface of a gill-filament; intended to show the relative size, shape, and position of the cells as seen in a transverse section. This drawing must be taken as correcting deficiencies in figs. 9, 10, 11.

Dreissena.

Fig. 24.—Portions of two transverse sections of a gill-plate of Dreissena, showing the various arrangement of the large vertical channels or vessels in relation to the interlamellar junctions.

Figs. 25—29.—See below, Plate VII.

Fig. 30.—Dense form of lacunar tissue, with closely packed fusiform cells. This tissue is found in the interlamellar junctions of Dreissena, and also in those of Anodon, but it seems periodically and locally to give place to the looser typical form of lacunar tissue with trabeculæ.

Fig. 31.—Similar dense lacunar tissue, forming a branched complex trabecula.

Plate VII.—Dreissena.

Fig. 25.—Transverse section through a gill-plate of Dreissena, showing two interlamellar junctions, one of which (the left) consists at this point of dense lacunar tissue with fusiform cells; whilst the other has trabeculæ only and floating corpuscles. The upper lamella exhibits five filaments in section; the section passing along the horizon of a transverse fibrous junction. The lower lamella has its six filaments free from transverse junction. Note the small size in these of the subfilamentar outgrowths as compared with Anodon. Obj. 8, oc. 4.

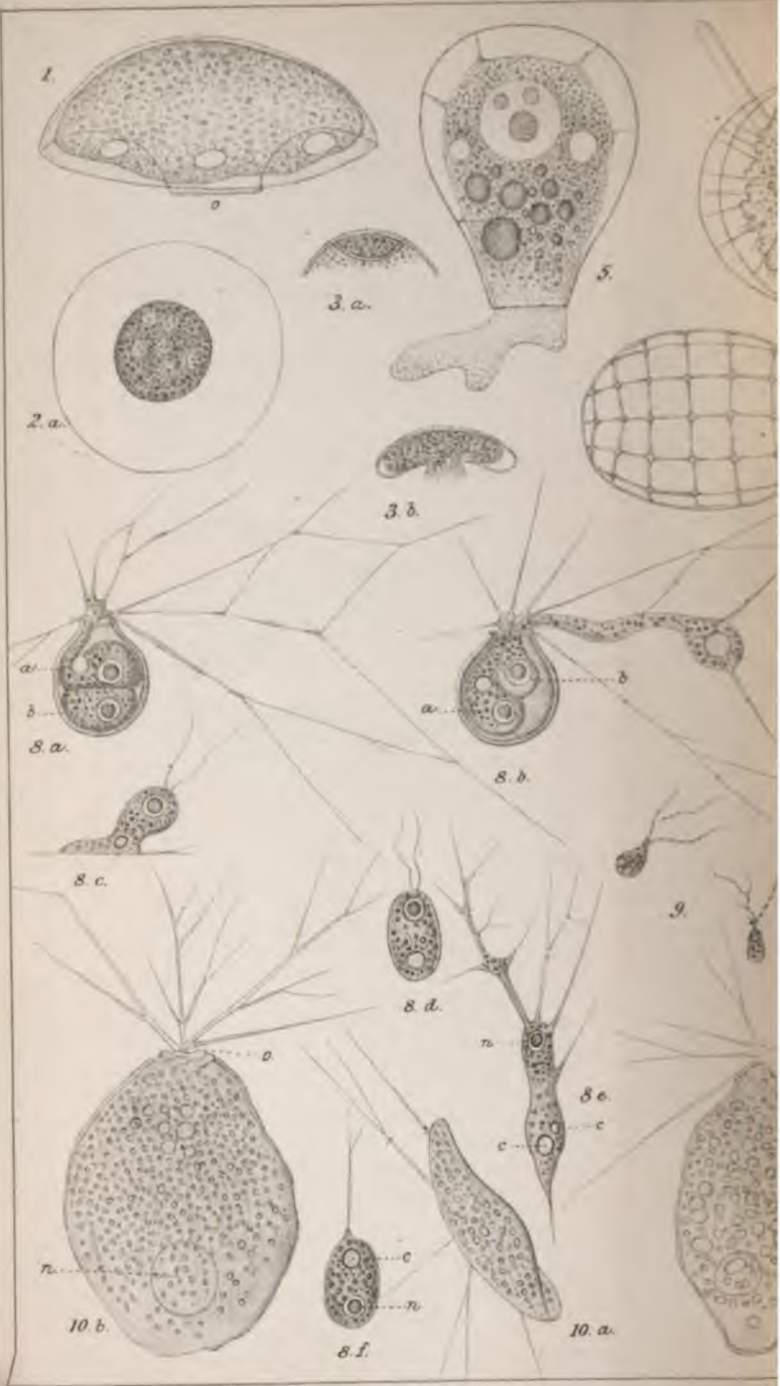
Fig. 26.—Two filaments in transverse section more highly magnified. The peculiar outgrowth of the chitinous axis of the filament, and its relation to the lacunar tissue, is to be noted. The section is not far from the horizon of a transverse interfilamentar junction. By the side of the filaments is a view from the supra-lamellar aspect of one of the large latero-frontal cells. (From a drawing by Mr. Lankester.)

Fig. 27.—View from the supra-lamellar aspect of the surface of a portion of three gill-filaments of Dreissena, showing the few nuclei of the frontal epithelium and the bordering latero-frontal epithelium.

Fig. 28.—Diagram showing part of three filaments, transverse fibrous junctions, subfilamentar tissue, and stomata of water-passages of Dreissena.

Fig. 29.—Diagram of part of four filaments, with two transverse fibrous junctions.

N.B.—In none of the plates are the figures drawn to a constant scale. For the actual dimensions of the objects figured the reader is referred to the text.


1.
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10. a.

EXPLANATION OF PLATE VIII,

Illustrating Mr. Archer's Résumé of Recent Contributions to our Knowledge of "Freshwater Rhizopoda."

FIG. 1.—*Pseudochlamys patella*, seen from the side, the delicate membrane forming the oral portion of the test is seen prominent below (*o*). (After Hertwig and Lesser, drawn under "Zeiss. F. Oc. III.")

FIG. 2*a*.—*Pseudochlamys patella*, without processes of attachment or pseudopodia, perfectly at rest, flatly expanded (after F. E. Schulze). × 400. 2*b*. The same, the test folded together, distinct processes of attachment and a single long finger-like pseudopodium (after F. E. Schulze). × 500.

FIG. 3*a*.—"Encysted" state of *Pseudochlamys patella* (seen laterally). × 400. 3*b*. Showing an infolded condition of the lower (oral) portion of the test. × 400. (From Irish specimens.)

FIG. 5.—*Hyalosphenia lata*, F. E. Schulze, viewed from the broad aspect, with a somewhat divided finger-like pseudopodium.

FIG. 6.—Posterior view of *Quadrula symmetrica*.

FIG. 8,—*a*. Development of the zoospores in *Microgromia socialis*, a single individual of the colony transversely dividing into two portions; *a*, the persistent anterior portion; *b*, the posterior portion, which subsequently forms the zoospore; 8*b*, representing the posterior portion, *b*, during its exit; 8*c*, its modification into a zoospore; 8*d*, the zoospore (formed from the portion *b* of fig. 8*a*); 8*e*, the young individual after leaving the mother-colony—at the anterior end the nucleus, *n*—at the posterior the contractile vacuoles, *c*, *c*; 8*f*, the young individual come to rest, the end possessing the contractile vacuole still forms the anterior portion and sends out a protoplasmic process corresponding to the pseudopodial stem.

FIG. 9.—*Microgromia mucicola*, Archer, n. s., three individuals; two show a mutually inosculated pseudopodinm.

FIG. 10.—*a*. *Plagiophrys scutiformis*, Hertw. et Less., *n*, nucleus, *o*, pseudopodial opening; the example is seen from its broader aspect; a formation of vacuoles is seen in the protoplasm, regarded as indicative of impending death; 10*b*, the same seen from the aboral pole.

FIG. 11.—*Plagiophrys sacciformis*, Hertw. et Less., the end possessing the pseudopodial opening contracted in a necklike manner by the infolding of the membranous test.

EXPLANATION OF PLATE IX,

Illustrating Mr. Sydney H. Vines' Account of Professor Strasburger's Observations on Protoplasm.

Figs. 1, 2, 3, 4, and 6, after Strasburger.

Fig. 5, after Hofmeister.

Figs. 1—3, and 6, Vaucheria sessilis.

Fig. 1.—Nearly mature zoogonidium in its case. Prepared with alcohol. × 240.

Fig. 2.—Anterior portion of same, in fresh state. × 600.

Fig. 3.—A portion of the ectoplasm with cilia, osmic acid. × 600.

Fig. 6.—Portion of a zoogonidium which had been induced to form a second cellulose membrane; fresh state. × 600.

Figs. 4 and 5.—Æthalium septicum (Myxomycetes).

Fig. 4.—Portion of a plasmodium in process of retraction; fresh state × 600.

Fig. 5.—Portion of a plasmodium in process of retraction. × 200.

Fig. 1.

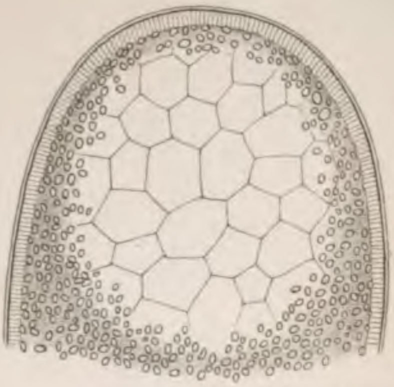

Fig. 2.

Fig. 4.

Fig. 5.

Fig. 3.

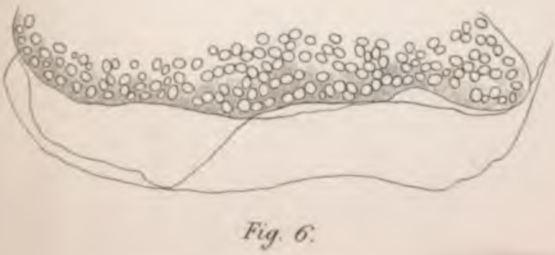

Fig. 6.

EXPLANATION OF PLATE X,

ıg Professor Van Beneden's Researches on the Dicyemidæ.

ı young *Dicyemopsis macrocephalus* (prep. osmic acid im- 10, oc. 2). The head has not yet assumed the characteristic ;enus. It is still convex in front and the cells of the polar ill arranged as they are in *Dicyema typus*. They are dis- om the cells of the trunk by their finely granular appear- oarapolar cells still resemble the other cells of the trunk. toderm is very transparent, and a few granulations can just ; cellular protoplasm. The nuclei of all the cells are oval nucleolus. In the cell of the endoderm there is seen—the ; cell (*n*), which is remarkable for its size, its elliptical form, ;ly well-defined outline; 2ndly, spherical spores or germs in s of development, each having a small nucleus; 3rdly, a o small homogeneous nuclei; 4thly, a germ divided into :s; 5thly, two vermiform embryos at different periods of seen in optical section, which are remarkable because in each to be a small central cell (*c c*) in the centre of the cephalic ately in front of the endodermic cell, which will, perhaps, with the axial cell after the disappearance of its nucleus, ıale cell.

he head of a very large *Dicyemopsis macrocephalus* (rhom- n in optical section, and drawn from an individual lying upon :e. The polar velum is shown as it appeared when the ob- cussed to show the optical section of the organism in its ion. (Prep. in osmic acid, obj. 10, oc. 2.) The eight cells elum are seen by transparency. The parapolar cells have ristic form, they are of great size, and possess large oval ıe axial cell is seen an infusoriform embryo fully developed, orotoplasmic network. The embryo always presents many lies in Dicyemopsis.

)icyemella Wageneri of *Eledone moschata* (obj. 8, oc. 2). nts a large nematogenous individual. whose movements many ways those of *Gregarina gigantea*. The absolute ıe folds remain unaltered; but from the movements of their position in relation to the body of the Dicyemella anges. The ectoderm is finely granular; here and there it er globules, which are collected together at two points to , *w*). The constituent cells of the ectoderm are not distin- n the clear endodermic cell, which is perfectly transparent y free from granulations, germs and vermiform embryos eat number.

ırt of the endodermic cell of a Dicyemella of *Eledone moschata*, germ producers and the nucleus of a germ producer (*n'*) ome free in the protoplasmic network (obj. 8, oc. 2).

erm producer of *Dicyemopsis macrocephalus* (obj. imm. 10, omes from a rhombogenous individual which contained germ producer placed near the nucleus of the axial cell rm producer shows three generations of germs, arranged in

concentric layers round the nucleus of the germ producer (n'). The germs of the latest generations are still lodged in the protoplasm of the germ-producing cell; their nuclei are still homogeneous, and their contour is only feebly defined.

FIG. 6.—The division of the two cells of a vermiform germ into four similar cells *Dicyemella Wageneri* (imm. 10, oc. 4).

FIG. 7.—The division of the previous cells into seven, of which one is large whilst the rest are small. *Dicyemella Wageneri* (imm. 10, oc. 4).

FIG. 8.—Gastrula of vermiform embryo of *Dicyemina Köllikeriana*, prep. in acetic acid (obj. immers. 10, oc. 2).

FIG. 9.—Vermiform larva of *Dicyemina Köllikeriana* (imm. 10, oc. 2).

FIGS. 10—15 apply to the development of infusoriform embryos.

FIG. 10.—Spherical germ of Dicyemella. The nucleus is striated, and exceedingly clear striæ follow the meridional lines and converge towards the two small refractive corpuscles situated at the poles.

FIG. 11.—An elliptical germ, with an elliptical nucleus; at the two extremities of the great axis the same polar corpuscles are seen. Near these is a layer of dark substance which perhaps foreshadows the division of the two halves of an equatorial plate. These are the nuclear discs; and between them are the meridional striæ. The median plane of the ellipse is marked by a series of dark points.

FIG. 12.—A germ in the same stage of development, seen along its main axis. In the centre is the polar corpuscle surrounded by the polar disc, and forming with it the derived pronucleus. This figure shows that the striation is due to filaments which are only found on the surface of the nucleus.

FIG. 13.—A more advanced stage of development. The derived pronucleus is surrounded by a layer of transparent substance, easily seen at the side and at the periphery (the engendered pronucleus).

FIG. 14.—A germ still further advanced. The intercellular plate extends to the surface. The derived pronucleus is attached to the engendered pronucleus.

FIG. 15.—Germ divided into four, the fusiform nuclei on the point of dividing.

FIG. 16.—Vermiform embryo in which the refractive bodies have just appeared. There are two large superficial cells (p) lying next each other, which form eventually the parietal cells of the urn, and two median cells (s), the superficial cells of the urn; the two cells (r) immediately in front of the preceding cells have given rise to the refractive bodies.

FIG. 17.—An embryo rather more advanced. *a*. In optical section; *b*, inferior face formed by the future ciliated cells; *p*, the parietal cells; *c*, superior face; *r*, cells of the refracting body; *s*, superficial cells of the urn; *i*, granular body.

FIG. 18.—Infusoriform embryo of *Octopus vulgaris*. The cover is not perfectly formed. The granular bodies are still in contact with the surrounding medium. The cap is rudimentary. The granular bodies are still uninuclear cells. (p) The two parietal cells forming the capsule ultimately; (s) the superficial cells modified to form the cover; (i) polynucleated cells of the interior of the urn.

FIG. 19.—Infusoriform embryo of *Dicyema typus* dissociated by maceration in hæmatoxylin for three hours. The refractive bodies have burst; ectocysts (ce); endocysts (ci); at the sides granular masses which have escaped from the internal capsules; (p) the border of the urn; (i) granular bodies (polynucleated cells) enclosed in the urn; (c) isolated cells of the ciliated body.

9

Fig. 2.

Fig. 3.

Fig. 5.

Fig. 7.

EXPLANATION OF PLATE XII,

Illustrating Mr. Kidd's paper on Some Points in the Early Development of the Hen's Egg.

In all cases *g* = germ; *s* = subgerminal layer; *y* = yolk.

Fig. 1.—Chromic-acid preparation. Incubated for fourteen hours. *g* is seen to be divided into two portions, separated by a thickened mass of *s*. Hartnack 2—4 in. tube.

Fig. 2.—Osmic-acid preparation. Incubated for twelve hours. Resembles 1, but segmentation here is less advanced. Hartnack 2—4 in. tube.

Fig. 3.—Osmic-acid preparation. Incubated for twelve hours. Segmentation more advanced than in 1 and 2. *s* Absent at left-hand side, but presents a wedge-shaped appearance at the right, and is divided off from the subjacent yolk by a fine cleft. Hart. 2—4 in. tube.

Fig. 4.—Chromic-acid preparation. Incubated for eight hours. Segmentation less advanced. Wedge-shaped mass of *s* at right side contains numerous nuclei. Hart. 2—7 in. tube.

Fig. 5.—Chromic-acid preparation. Incubated for fourteen hours. Segmentation more advanced here than in the others. Peripheral thickenings of *s* well marked at both ends. Hart. 2—4 in. tube.

Fig. 6.—Osmic-acid preparation. Incubated for twelve hours. The germ is seen to be in direct continuity with the subgerminal layer at one place. Both *g* and *s* richly nucleated. Peripheral thickenings of *s*. Well marked. Hart. 2—7 in. tube.

Fig. 7.—Chromic-acid preparation of a normal unincubated egg showing only the floor of the subgerminal cavity with a few large cells lying on it. The subgerminal layer here also is seen to be nucleated. Hart. 2—7 in. tube.

XPLANATION OF PLATE XIII,

Mr. Archer's Résumé of Recent Contributions
Knowledge of "Freshwater Rhizopoda."

cythium hyalinum, Hertwig et Lesser; *c*, non-contractile ucleus; the example is seen from the aboral pole, the opening turned downwards. (After Hertwig and Lesser, Zeiss, F. oc. III.")

he same (presumably); *n*, nucleus. (After Cienkowski.)

hlamidophrys stercorea, Cienk. An example showing two the equatorial granular zone. × 760.

itoum parvum, E. Schulze, seen from the flat side. × 800.

omia paludosa, Cienk. Shows the completion of the sub-wo. × 600.

yphoderia truncata, E. Schulze. The large, clear-looking e through and through. × 600.

Euglypha ampullacea, Hertwig et Lesser. The anterior est to show the form of the "teeth" surrounding the oral their relation to the series of hexagonal plates. (Drawn F. oc. III.)

enrophrys lageniformis, E. Schulze. × 600.

europhrys compressa, E. Schulze. *a* seen from the edge, *b* d aspect. The nucleus seen through and through. × 800.

EXPLANATION OF PLATE XIV,

Illustrating Mr. E. Cresswell Baber's paper on the Lymphatics and Parenchyma of the Thyroid Gland of the Dog.

Fig. 1.—From a transverse section of the thyroid gland, injected with Berlin blue and stained with picrocarminate of ammonia (Vérick's Obj. 6; Oc. 1).

a. Lumen of an artery, seen in transverse section.

b. Cross section of a large lymphatic vessel surrounding it. This is seen filled with a granular material stained yellow in the specimen. The dark outline indicates the position occupied by the Berlin-blue injection.

c. Contents of the vesicles, presenting a similar appearance to *b*.

d. Walls of the gland-vesicles, the epithelial cells of which are flattened by the action of the reagents.

Fig. 2.—Lymphatic tubes showing endothelium, from a transverse section of the gland injected with silver. In this section, which is thick, the tubes, which in the drawing appear on one level, are situated on various planes, and frequently dip down among the vesicles (Obj. 3; Oc. III).

Fig. 3.—From a longitudinal section, showing several parenchymatous cells (with unshrunken cell-substance) situate at various distances from the interior of the vesicles (*a a*). Some are separated from the cavity of the vesicle by merely a membrane (*c*), others by flattened epithelial cells, and others again by normal epithelial cells. Between *a* and *a* is a cavity, from which a parenchymatous cell has probably escaped (Obj. 8; Oc. I).

Fig. 4.—From a longitudinal section, showing three parenchymatous cells (*b*) apparently situate in a common cavity. The wall of the neighbouring vesicle has become flattened out, and the flattened epithelial cells have separated, placing the parenchymatous cells in free communication with the interior of the vesicle (*a*).

Fig. 1.

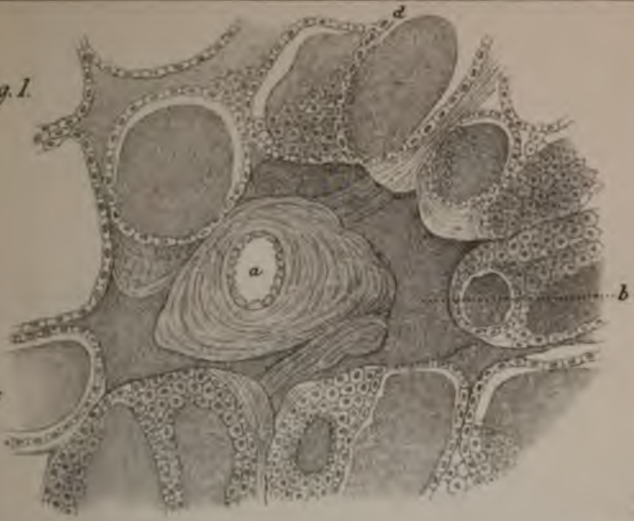

Fig. 4.

Fig. 2.

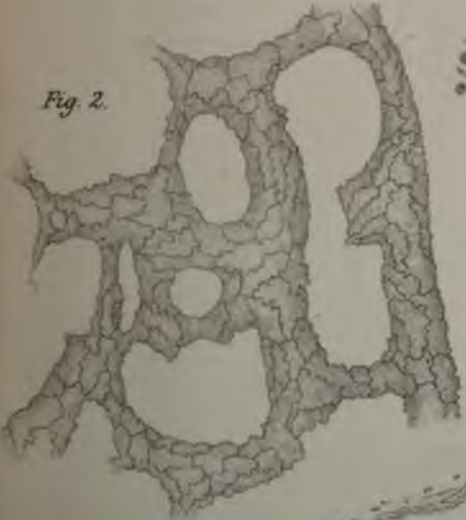

Fig. 3.

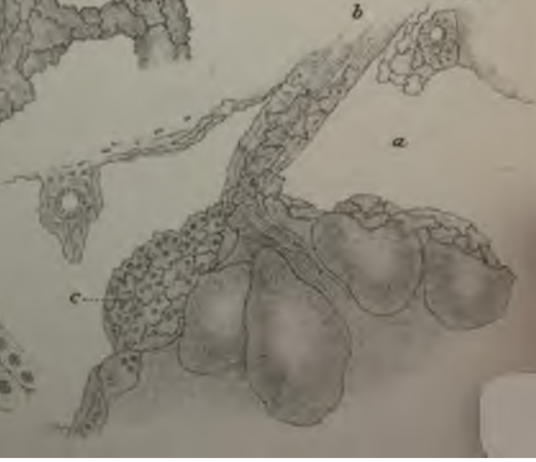

Fig. 5.

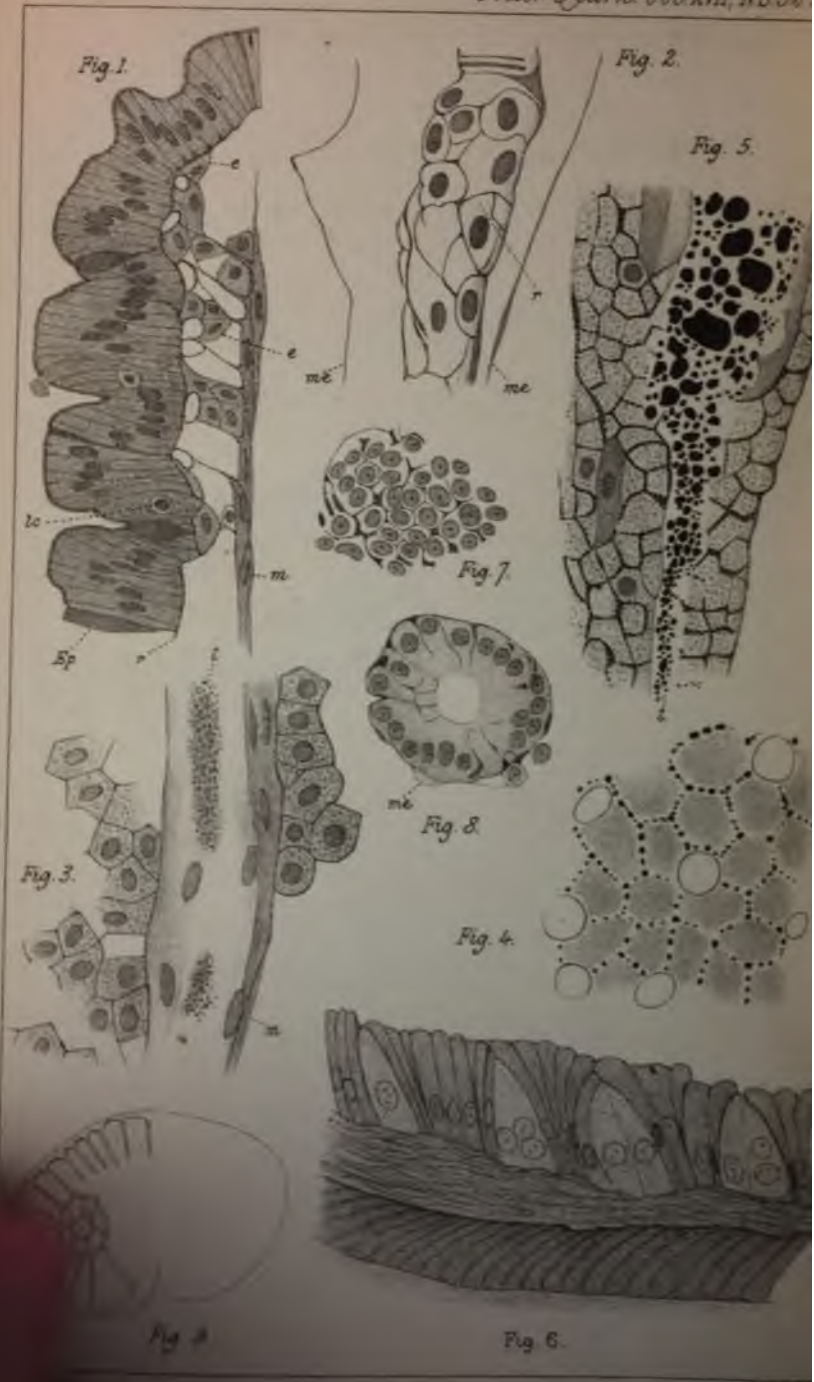
Fig. 1.
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Fig. 2.
Fig. 5.
Fig. 7.
Fig. 8.
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Fig. 3.
t
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Fig. 4.
Fig. 6.

EXPLANATION OF PLATE XV,

Illustrating Dr. Herbert Watney's paper on the Minute Anatomy of the Alimentary Canal.

The outlines of many of the preparations were drawn with an Oberhaeuser's camera lucida; in such cases the lens used with the camera lucida and the approximate magnification are given. The ocular and objective which were used in completing the drawing are also given.

The preparations from which these drawings are made were hardened in chromic acid and alcohol, except where the contrary is expressly stated in the following explanations.

FIG. 1.—Oc. III; Obj. 8, × 400. Section of a villus from the small intestine of a monkey.

- *m.* A band of involuntary muscle-fibres. The connective-tissue reticulum surrounding the individual fibres is attached to the membrana propria.
- *ep.* Epithelium. The epithelial cells are seen to be of different lengths.
- *r.* Dark line at the base of the epithelial cells caused by the reticulum.
- *l. c.* Lymph-corpuscle.
- *e.* Endothelial cells of the membrana.
- *v.* Blood-vessels.

The great similarity of the cells of the villus to the cells composing the membrana is seen.

FIG. 2.—Camera lucida: Obj. 7, × 450. Oc. III; Obj. 9. Vertical section of the lower part of a villus from the small intestine of a monkey, showing a large vein.

- *me.* Section of the membrana propria.
- *r.* Reticulum.

The endothelial cells of the vein are seen to be surrounded by a very delicate reticulum.

FIG. 3.—Camera lucida: Obj. 7, × 450. Oc. III; Obj. 9. Section of the lower part of a villus from the small intestine of a hedgehog.

- *l.* Central chyle-vessel, containing a little granular matter.
- *m.* A small band of muscles; they are in contiguity with the wall of the chyle-vessel.

The reticulum is attached to the wall of the chyle-vessel, and passes between the cells of the villus.

FIGS. 4 and 5.—From the villi of a hedgehog, killed during absorption of fat. The intestine was hardened with osmic acid.

FIG. 4.—Oc. III; Obj. 11 Immersion, × 850. Surface view of the epithelium, teased and treated with caustic potash.

The fat is seen as small black particles between the epithelial cells. The clear spaces are the openings of the goblet cells.

FIG. 5.—Camera lucida: Obj. 7, × 450. Oc. III; Obj. 8. Section of the lower part of a villus.

l. Chyle-vessel.

In the upper part of the figure the fat-particles in the chyle-vessel have run together. The fat-particles are seen in the reticulum of the villus.

FIG. 6.—Camera lucida: Obj. 5, × 300. Oc. III; Obj. 8. Section of a short villus-like process: from the stomach of a dog, showing the "epithelial buds."

The nuclei of the cells composing the bud-like groups are spherical, and are less stained than those of the neighbouring cells.

FIG. 7.—Camera lucida: Obj. 5, × 300. Oc. III; Obj. 8. Surface view of one of the terminal alveoli of the proper gland-tubes, from the pyloric end of the stomach of a dog; the animal was killed two hours after meat food.

A delicate reticulum is seen surrounding the epithelial cells.

FIG. 8.—Camera lucida: Obj. 5, × 300. Oc. III; Obj. 8. Oblique section of one of the terminal alveoli of the proper gland-tubes; from the pyloric end of the stomach of a dog. The animal was killed two hours after meat food.

mc. Membrana propria.

The nuclei and the reticulum are both clearly seen.

FIG. 9.—Camera lucida: Obj. 5, × 300. Oc. III; Obj. 8. Section of one of the terminal alveoli of the proper gland-tubes; from the pyloric end of the stomach of a dog. The stomach had been hardened in osmic acid, and subsequently in chromic acid.

The reticulum has a double outline, and is much broader than in fig. 7.

LANATION OF PLATE XVI,

Angelo Andres' paper on a New Genus and *Zoanthina Malacodermata* (*Panceria spon-* n.).

pongiosa, sp. n., natural size.
ial section × 2—*t*, tentacles; *s*, stomach; *b*, branchia-
;ans; *f*, convoluted filaments; *m*, anastomosing mesen-
α, *β*, *γ*, *δ*, *ε*, *ζ*, places corresponding to the sections of
g figures.
erse sections at points *α*—*ζ* of foregoing figures.
section *δ* much enlarged—*a*, cuticle; *b*, subcuticle; *c*,
n; *d*, connective tissue; *e*, muscular layer; *f*, endo-

:ctoderm (610 diam.).
ous elements of mesoderm (610 diam.).

EXPLANATION OF PLATE XVII,

Illustrating Dr. Sangster's Paper on Observations on the Muscular Coat of Sweat-Glands.

Fig. 1.—From a transverse section through the skin of a sheep (sheep-pox, Klein), showing part of the coiled tubule of a sweat-gland.

(A). In transverse,

(B). In longitudinal section.

(A). *a.* Degenerated epithelium. *b.* The muscular coat divided transversely and somewhat obliquely. *c.* The transversely cut, staff-shaped nuclei. *d.* "Membrana propria." *e.* Connective tissue (œdematous).

(B). *a.* Epithelium. *b.* Longitudinally cut muscular coat. *c.* The staff-shaped nuclei. *d.* Membrana propria (Hartnack, Eyepiece III; Obj. 8).

Fig. 2.—From a transverse section through the skin of the ear-lobe of pig, showing part of the coiled tube of a sweat-gland in transverse section.

a. Epithelium. *b.* Muscular coat cut transversely. *c.* Nucleated membrane forming the boundary of fibrous tissue around gland-tube. *d.* Connective tissue (Hartnack, Eyepiece III; Obj. 7).

Fig. 3.—From a transverse section through the skin of external auditory meatus (human), showing part of the coiled tubule of a ceruminous gland in transverse section.

a. Epithelium with granular matter. *b.* Transversely cut muscular coat with nuclei. *c.* "Membrana propria." *d.* Connective tissue (Hartnack, Eyepiece III; Obj. 8).

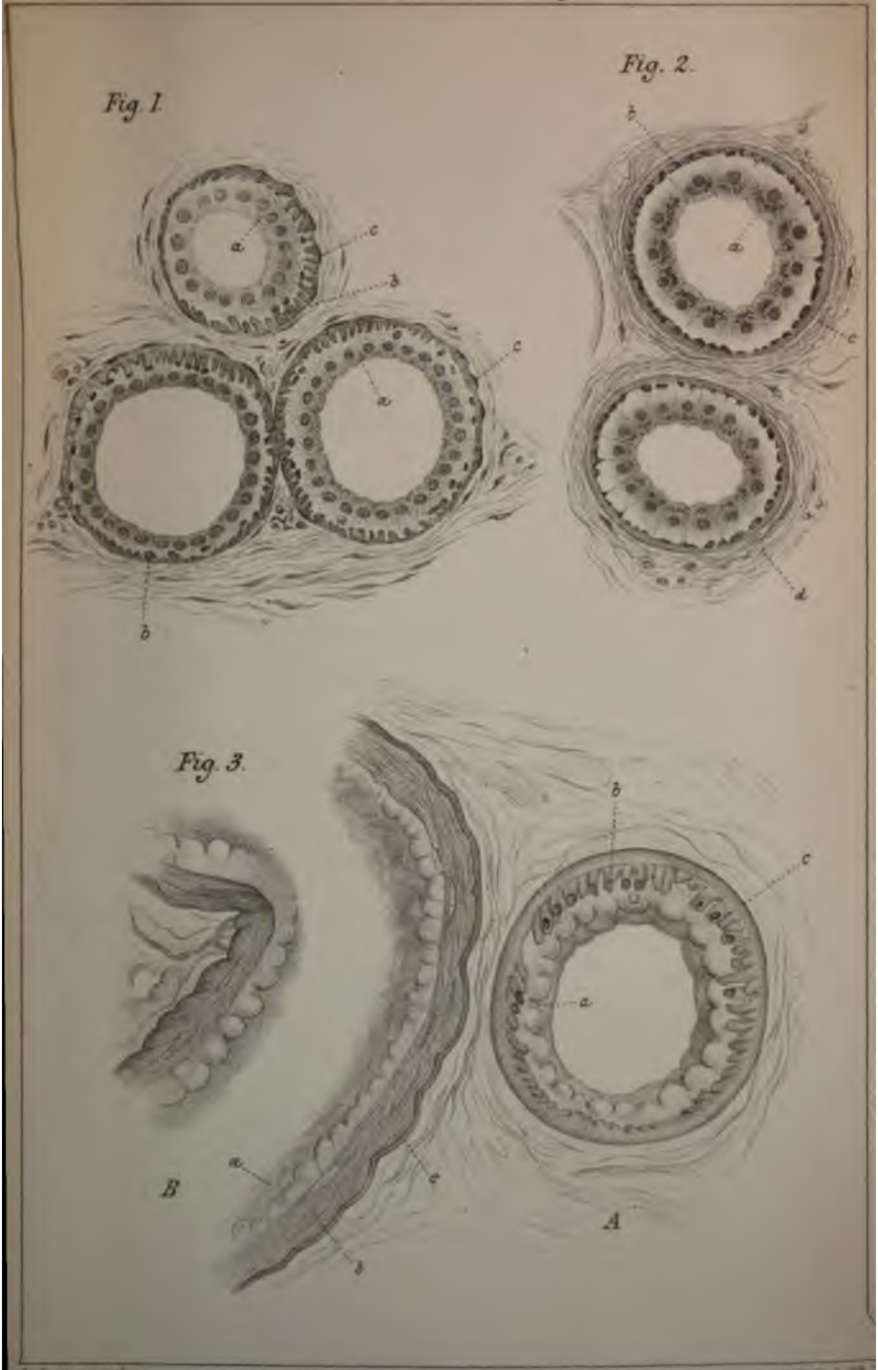


Fig. 1.
a
b
c
Fig. 2.
a
b
c
d
Fig. 3.
a
b
c
A
B

DESCRIPTION OF PLATE XIX,

Illustrating Mr. Francis Darwin's Paper on the Protrusion of Protoplasmic Filaments from the Glandular Hairs on the Leaves of the Common Teasel (*Dipsacus sylvestris*).

Fig. 1.—A trichome of the kind which neither secretes resin nor produces filaments. × 420, *camera lucida*, Hartnack obj. No. 8.

Fig. 2.—Gland bearing a long and stout filament. × 420, *camera*, Hartnack No. 8.

Fig. 3.—Gland bearing a simple filament and two other small protoplasmic masses, one cylindrical, the other partly spherical. × 420, *camera*, Hartnack No 8.

Fig. 4.—The same gland, showing the three masses united into one through contraction produced by dilute acetic acid.

Fig. 5.—Summit of a gland bearing a filament killed by one per cent. osmic acid, and afterwards changed into a "soap-bubble" mass. × 420, Hartnack No. 8.

Fig. 6.—Gland bearing a complicated mass of filaments, consisting either of a single branching filament, or of several entangled together. × 170 (*camera sketch*), Hartnack No. 5. *In this drawing the filament is represented by a single line.*

N.B.—The filament was in movement, and continually changing its appearance, so that it was impossible to copy it with absolute fidelity.

Fig. 7.—Gland from specimen which had been mounted about a quarter of an hour previously, in ½ per cent. carbonate of ammonia. It shows the characteristic rounded masses of delicate transparent protoplasm which exhibit amœboid movements. × 420, *sketched with camera*, Hartnack No. 8.

Fig. 8.—Gland with filament in the condition in which slow changes of form occur from some unknown cause (see p. 262). × 420, *sketched with camera*, Hartnack No. 8.

Fig. 9.—Same gland, showing the changes which have taken place within half an hour. Fig. 9 also illustrates the "moniliform" condition which often precedes contraction.

Fig. 10.—Aggregation of the *contents* of a gland into amœboid masses. From a specimen left in water from August 22—26, and which was therefore exposed to a nitrogenous fluid. × 500, *camera*, Hartnack No. 9.

Fig 11.—From a specimen left in infusion of meat from July 20—26. Besides the three glands are shown enormous masses of highly refracting protoplasm, which underwent spontaneous changes of form. (Dotted lines show a doubtful union of two portions.) × 255, *camera*, Hartnack No. 5.

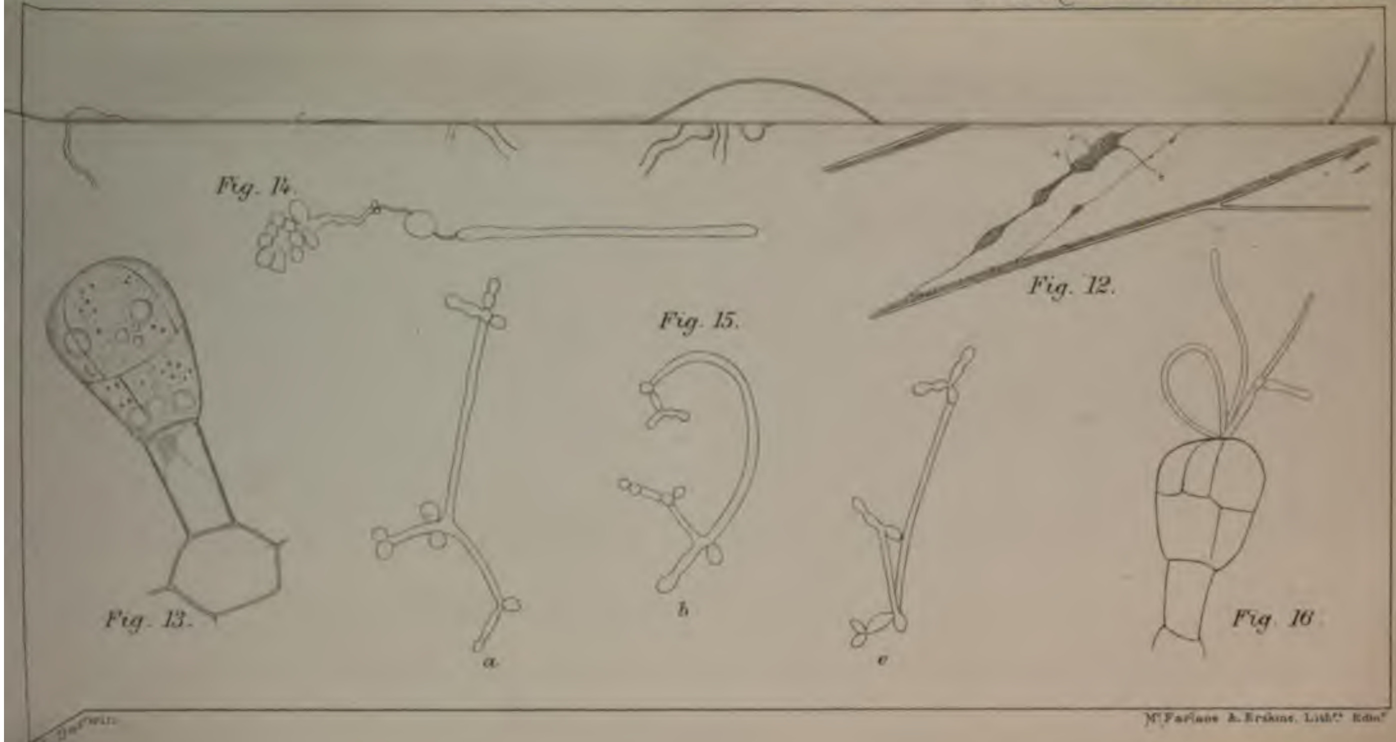
Fig. 12.—Part of a large, simple, non-glandular hair from a seedling leaf; the protoplasmic network has thrown out three filaments (marked *), which project freely into the cell-sap. × 420, *sketched with camera*, Hartnack No. 8.

Fig. 13.—Well-developed gland, containing drops of resin within gland-cells. × 420, *camera*, Hartnack No. 8.

Fig. 14.—Freely floating mass of protoplasm. × 500, *camera*, Hartnack No. 9.

Fig. 15, A, B, and C.—A free mass of protoplasm in active movement. Sketched with *camera* three times in five minutes. × 630, Hartnack No. 8.

Fig. 16.—Transparent filaments (looped and branching), from specimens treated with ½ per cent. carbonate of soda. × 420, *camera*, Hartnack No. 8.



F. Darwin.
McFarlane & Erskine, Lith^rs Edin^r

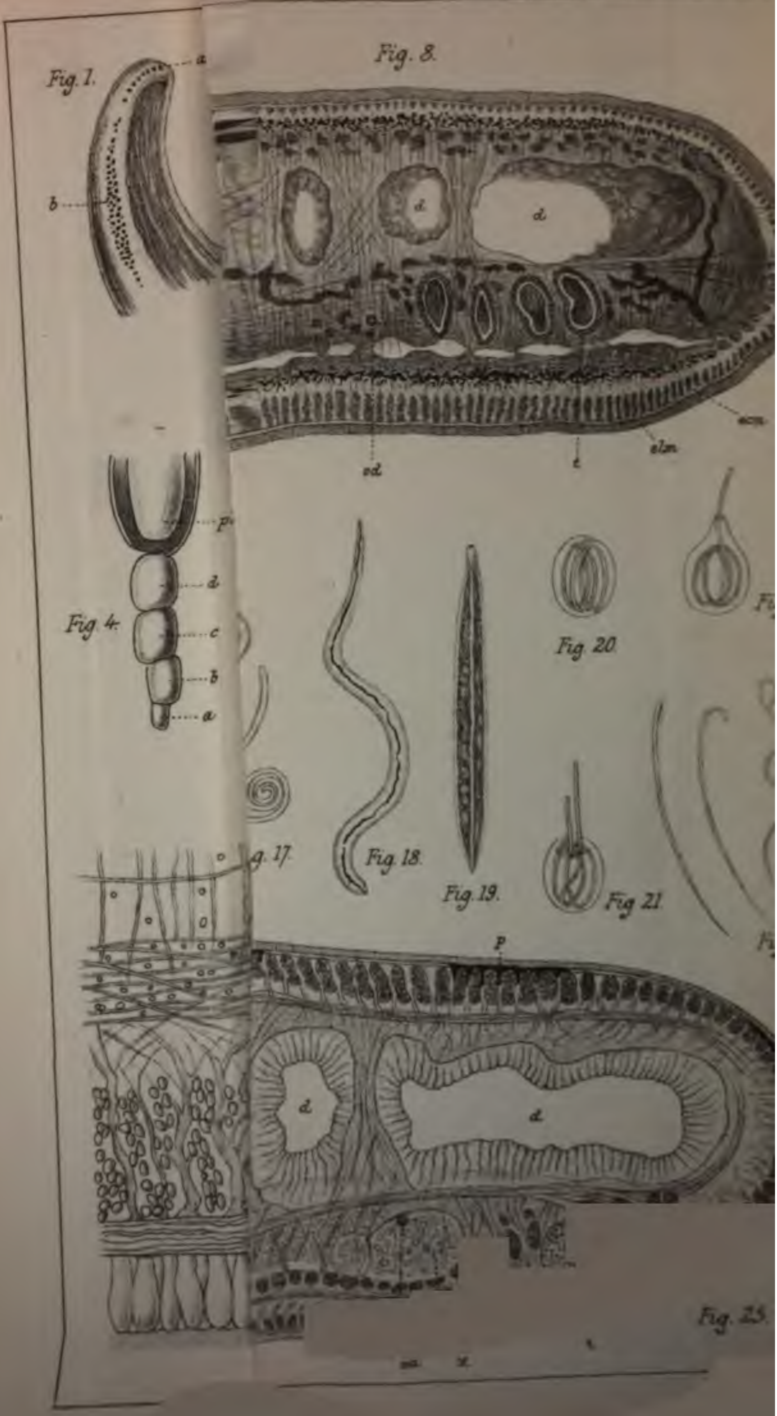


Fig. 1.
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Fig. 8.
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Fig. 4.
g. 17.
Fig. 18.
Fig. 19.
Fig. 20.
Fig. 21.
p
d
d
Fig. 25.

JOURNAL OF MICROSCOPICAL SCIENCE.

DESCRIPTION OF PLATE XX,

Illustrating a Paper on the "Structure of Various Land Planarians." By H. N. Moseley, M.A., F.R.S., Fellow of Exeter College, Oxford.

FIG. 1.—Anterior extremity of *Geoplana Traversii* viewed from the side to show the arrangement of the eye-spots.

a. Elongate patch of several rows of eye-spots. *b.* Single row of eye-spots on the anterior tip of the body. Enlarged.

FIG. 2.—Three of the eye-spots of the same more highly magnified to show the oval spaces clear of pigment in which they lie.

FIG. 3.—Diagrammatic representation of the arrangement of the viscera in the same as viewed from the dorsal aspect. The integument and muscles are supposed to be removed from the dorsal surface so as to expose the viscera *in situ*. The sheath or sac of the pharynx and that of the generative organs are laid open. The diverticula of the digestive tract are traced for a short distance on the left side of the body only.

m. Circle showing the position of the mouth or aperture of exit of the pharynx. *ph.* Pharynx lying within its sac or sheath. *i i.* Intestine, a single mesially placed tube in the anterior region of the body, but double in the hinder part, forking at the root of the pharynx, the two tubes thus formed passing one on either side of the sheath of the pharynx and generative organs. *s.* Septum, separating the two intestinal canals in the hinder extremity of the body. *o.* Ovary. *od.* Oviduct. *u.* Uterus. *t.* Testis. *v d.* Vas deferens. *v s.* Vesicula seminalis. *e j.* Ejaculatory duct. *b p.* Bulb of the penis. *x.* Accessory bulb. *a.* Cavity of the common sac containing the generative organs. The special coverings of the various generative organs are dissected away. *g o.* Position of the generative outlet.

FIG. 4.—Generative organs of the same with their special coverings intact.

a. Sac containing the uterus. *b.* That containing the accessory bulb. *c.* That containing the bulb of the penis and part of the ejaculatory duct. *d.* That containing the vesicula seminalis and upper part of the duct.

FIG. 5.—The generative organs of the same, seen from the side removed from their sheaths and coverings.

v d. Vas deferens. *v s.* Vesicula seminalis. *e j.* Ejaculatory duct. *b p.* Bulb of the penis. *x.* Accessory bulb. *p.* Penis. *g a.* generative aperture. *u.* Uterus. *od.* Oviduct.

FIG. 6.—View of the lateral wall of the main digestive canal of the same, showing the manner in which the diverticula open into the canal.

FIG. 7.—Egg capsule of the same, cut open to show four fully formed embryos within. In two of these the projecting pharynx is seen and one embryo has been removed from the capsule.

DESCRIPTION OF PLATE XX.—*continued.*

Fig. 8.—Transverse section of the body of the same, at a point a little anterior to the position of the pharynx.

e. Epidermis. *e c m.* External circular muscles. *e l m.* External longitudinal muscles. *p.* Pigment layer. *g.* Glandular structures. *i.* Main digestive canal. *d d.* Diverticula of the same. *t r m.* Transverse muscular fibres. *x.* Lateral organ. *od.* Oviduct. *t.* Testis.

Fig. 9.—Portion of the foregoing section, much enlarged to show the arrangement of the muscles in the inferior region of the body.

e. Epidermic layer, with its cilia. *e c m.* External circular muscular layer. *e l m.* External longitudinal muscles, cut across. *r m.* Radiating muscles. *t r m.* Transverse muscles. *l m.* Internal longitudinal muscles, cut across.

Fig. 10.—*Geoplana flava* from Bahia, viewed from the dorsal surface. × 2.

Fig. 11.—Amœboid cell from the same.

Fig. 12.—Various tissue elements of the same.

Fig. 13.—Vertical section of the mucous membrane of the digestive diverticula of the same, showing the ciliation and component cells.

Fig. 14.—Rod-cell from the same. Actual longer diameter ·035 mm. in length.

Fig. 15.—Similar cell containing partly coiled-up rods.

Fig. 16.—Young rod-cell of the same, containing developing rods.

Fig. 17.—Long rods of the same, which have emerged from their cells.

Fig. 18.—*Rynchodemus flavus*, viewed from the dorsal aspect. × 1½.

Fig. 19.—*Rynchodemus fuscus*, viewed also from the dorsal aspect. × 3.

Fig. 20.—Rod-cell of *Rynchodemus flavus*, showing coiled-up rods within.

Figs. 21 and 22.—Similar cells, with the rods partially protruded from the cell.

Fig. 23.—Rods of the same, which have emerged from the cells.

Fig. 24.—Section of the outer surface of the body of the same, as seen in fresh condition after slight pressure has been exerted on the section and the rods have thus been caused to be shot out.

a a. Protruded rods. *b b.* Contents of slime glands discharged. *e.* Epidermis, with short cilia.

Fig. 25.—Vertical section in the region of the body, anterior to the position of the pharynx of *Dolichoplana Philippensis*.

e. Epidermis. *e c m.* External circular muscles. *e l m.* External longitudinal muscles. *p p.* Pigment patches. *t r m.* Transverse muscles. *r m.* Radiating muscles. *i l m.* Internal longitudinal muscles. *a.* Special layer of internal longitudinal muscles. *b.* Special layer of transverse muscles. *l.* Main digestive canal. *d d d.* Diverticula. *od.* Oviduct. *t.* Testis. *x.* Lateral organ.

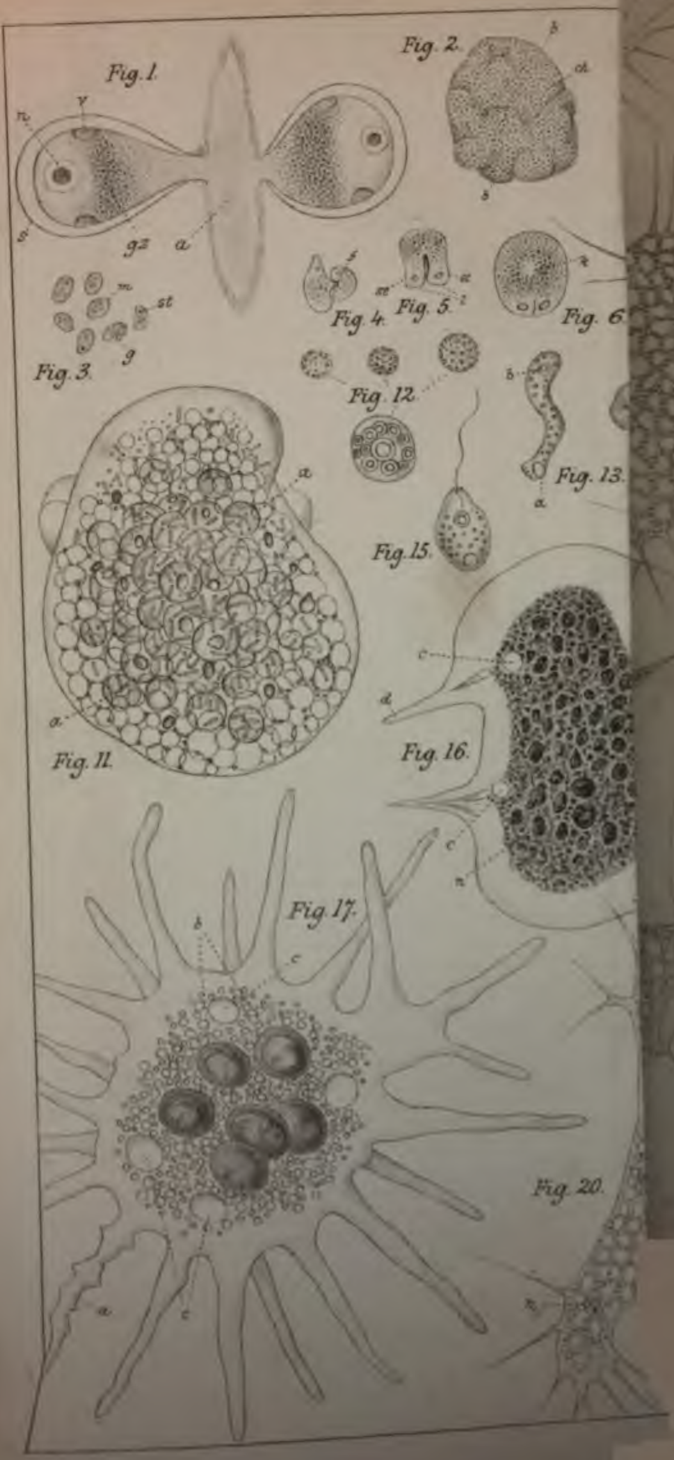
Fig. 1.
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Fig. 4.
Fig. 5.
Fig. 6.
Fig. 12.
Fig. 13.
Fig. 15.
Fig. 11.
Fig. 16.
Fig. 17.
Fig. 20.

EXPLANATION OF PLATE XXI,

Illustrating Mr. Archer's Résumé of Recent Contributions to our Knowledge of "Freshwater Rhizopoda."

Fig. 1.—*Troglodytes zoster*, Gabriel. Two examples in conjugation; *a*, fusion of the pseudopodia, *n*, nucleus with nucleolus, *s*, the test, *v*, the upper, larger vacuoles, *gz*, the granulated zone, with the "zoster"-granules. (Amplification not stated.)

Fig. 2.—The same, showing the cleavage of the coarsely granular germ-mass.

Fig. 3.—The same, "monostigma-form;" *m*, a monostigma, *g*, early granulation, *st*, the "stigma."

Fig. 4.—The same, fusion of the monostigma-form; *f*, the connecting process.

Fig. 5.—The same, "diplostigma-form;" *l*, the stigma-poles not coalesced, *st*, stigmata.

Fig. 6.—The same, the first indication of the nucleus.

Fig. 7.—The same (a young example complete); *n*, nucleus, *v*, vacuoles, *p*, the linear pseudopodia.

Fig. 8.—Presumably a young state of *Cochliopodium*, after Hertwig and Lesser.

Fig. 9.—*Ditrema flavum*, Archer (showing pseudopodia extended and median nucleus). × 400.

Fig. 10. *Pelomyxa palustris*, Greeff, in a contracted globular condition, richly charged with food- and sand-particles. At the margin the hyaline cortical protoplasm projects in waves from the dark body. × 60.

Fig. 11.—The same, young, × 300—400; *a a*, the shining bodies, "Glanzkörper," showing also the vacuoles and bacillar bodies.

Fig. 12.—The same, nuclei and their probable development into the shining bodies; *b*, nuclei of the ordinary size; *k*, some of these, the "nucleoli," show the punctiform centre, others the central cavity.

Fig. 13. The same, the "Amœbæ;" *a*, contractile vacuole; *b*, nucleus.

Fig. 14.—The same. Their modification into—

Fig. 15.—The same, the flagellate condition.

Fig. 16.—*Hyalodiscus rubicundus*, Hertwig et Lesser, seen from above; *a*, hyaline colourless ectosarc; *b*, the endosarc, containing the brownish granules and discoloured food particles, with several (contractile?) vacuoles, *c c*, and a pale grey-coloured spot, corresponding to the nucleus, *n*; *d d*, folds of the ectosarc. ('Zeiss. E. oc. III.')

Fig. 17. *Dactylosphærium vitreum*, Hertwig et Lesser, yellow form; *a*, a pseudopodium at the moment of retraction; *b b*, balls of food; *c c*, non-contractile vacuoles.

Fig. 18.—*D. vitreum*, green form, the whole superficies beset with minute protoplasmic processes.

Fig. 19.—*Leptophrys cinerea*, Hertwig et Lesser. The interior so packed with food that no certainty as to a nucleus can be gained.

Fig. 20.—*Leptophrys elegans*, Hertwig et Lesser; *nu*, nuclei.

Fig. 21.—*Arachnula impatiens*, Cienk. × 320.

Fig. 22.—*Gymnophrys cometa*, Cienk. × 400.

Fig. 23.—*Plakopus ruber*, E. Schulze. A large example, with distinct nucleus, numerous vacuoles, its membranous pseudopodia, and a few short filamentary processes. × 500.

Fig. 24.—*Mastigamœba aspera*, E. Schulze. × 500.

EXPLANATION OF PLATE XXII,

Illustrating Rev. T. Hincks's Abstract of Prof. Vogt's Paper on Loxosoma.

Letters employed in the Plate to designate the various portions of the Structure.

ADULT ANIMAL.

A. The hood.
B. Body.
B′. Bud.
C. Vestibule.
D. Tentacular crown.
E. Digestive canal.
F. Stem.
G. Intestine proper.
H. Rectum.
J. Orifice of the hood.

EMBRYO.

M. Ciliary crown.
N. Rudimentary digestive canal.
O. Buccal mammilla.
R. Spectacle-organ.
S. Eye-specks.
T. Caudal appendage.

BUD.

V. Masses of cells.
W. Primitive fissure.
X. Pedal body.
Y. Pedal gland.
Z. Pedal groove.

ADULT ANIMAL.

a. Cuticle.
b. Hypodermic layer.
c. Palmiform cutaneous folds.
d. Tactile organ.
e. Sphincter of the hood.
g. Ciliary cells of the tentacle.
i. Mouth.
k. Anterior lip.
l. Posterior lip.
m. Œsophagus.
n. Stomach.
o. Hepatic cells.
r. Anal orifice.
s. Seminal vesicle.
t. Testicles.
u. Mass of zoosperms.
v. Rudiments of the generative organs.
w. Ova.
x. Ovisac.
y. Tentacular cilia.
z. Crenated edge of the aperture of the hood.
z′. Cells surrounding the exterior margin of the sphincter.

FIG. 1.—Adult female *Loxosoma*, viewed in profile.

FIG. 2.—Male, contracted, ventral surface, with two uneqally developed buds.

FIG. 3.—Male, dorsal surface. Testicles and seminal vesicle fully developed.

FIG. 4.—Male, ventral surface; mass of zoosperms escaping.

FIG. 5.—A young *Loxosoma* that has been fed with carmine, showing the course of the food through the digestive canal and the cavity of the hood.

FIG. 6.—Female viewed from behind, containing 10 ova in various stages of development, numbered 1 to 10.

FIG. 7.—A group of three ova united by the pedicles of the ovisacs. In the one on the left segmentation is complete (mulberry stage); that on the right is more advanced, and appears as a granulated mass; the one in the middle contains an embryo in course of development.

FIG. 8.—Embryo after liberation.

FIG. 9.—A young *Loxosoma*, developed from a bud, showing the rudimentary tentacles; the œsophageal funnel, with its large posterior lip; the stomach, as yet uncoloured by the hepatic cells; the *mammilla* of the pedal body, and the groove in the stem occupied by the pedal gland.

FIG. 10.—Tentacle, viewed in profile, showing the structure.

FIG. 11.—The tactile organ.

FIG. 12.—A bud, showing the rudimentary digestive canal destitute of internal cavity.

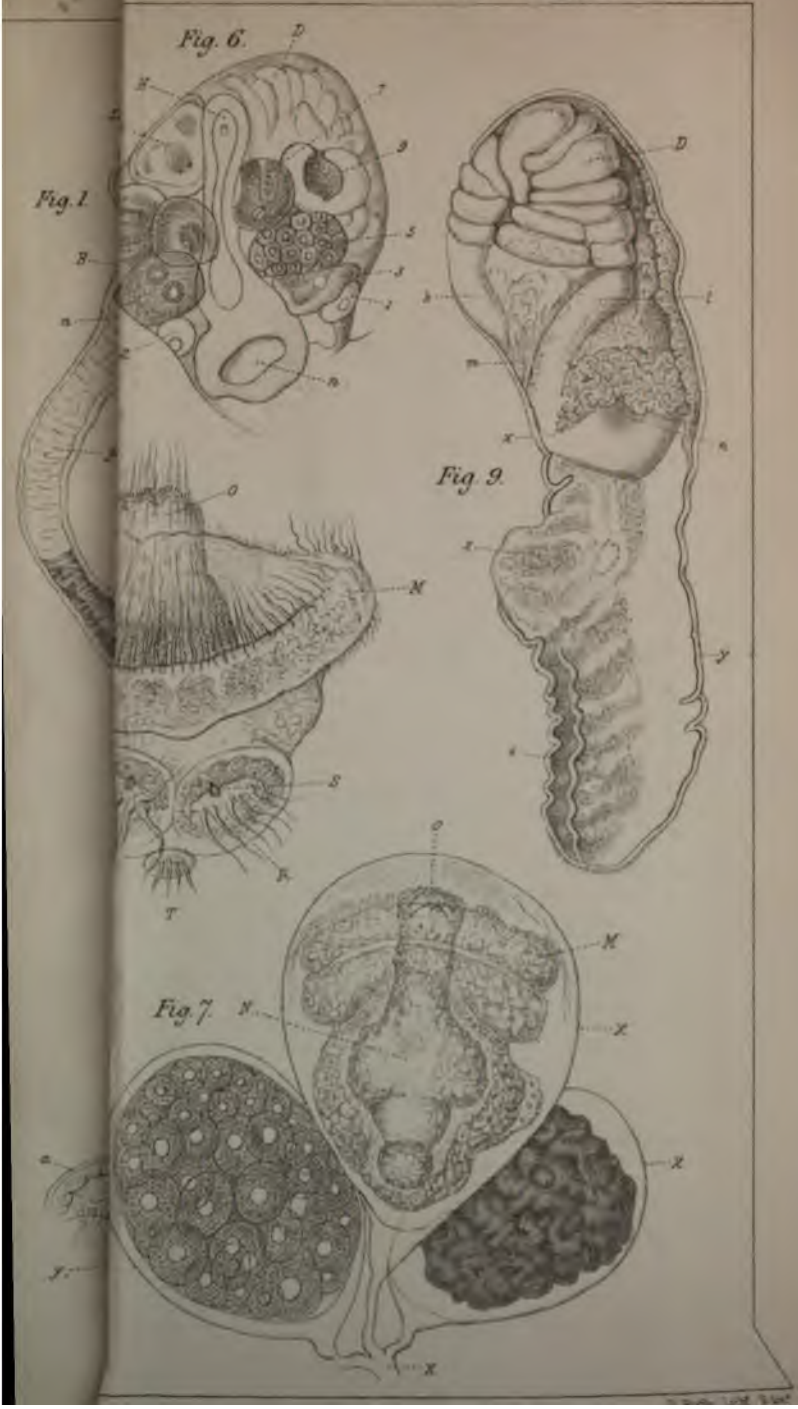


Fig. 6.
Fig. 1.
Fig. 9.
Fig. 7.

Fig. 2.

Fig. 1.

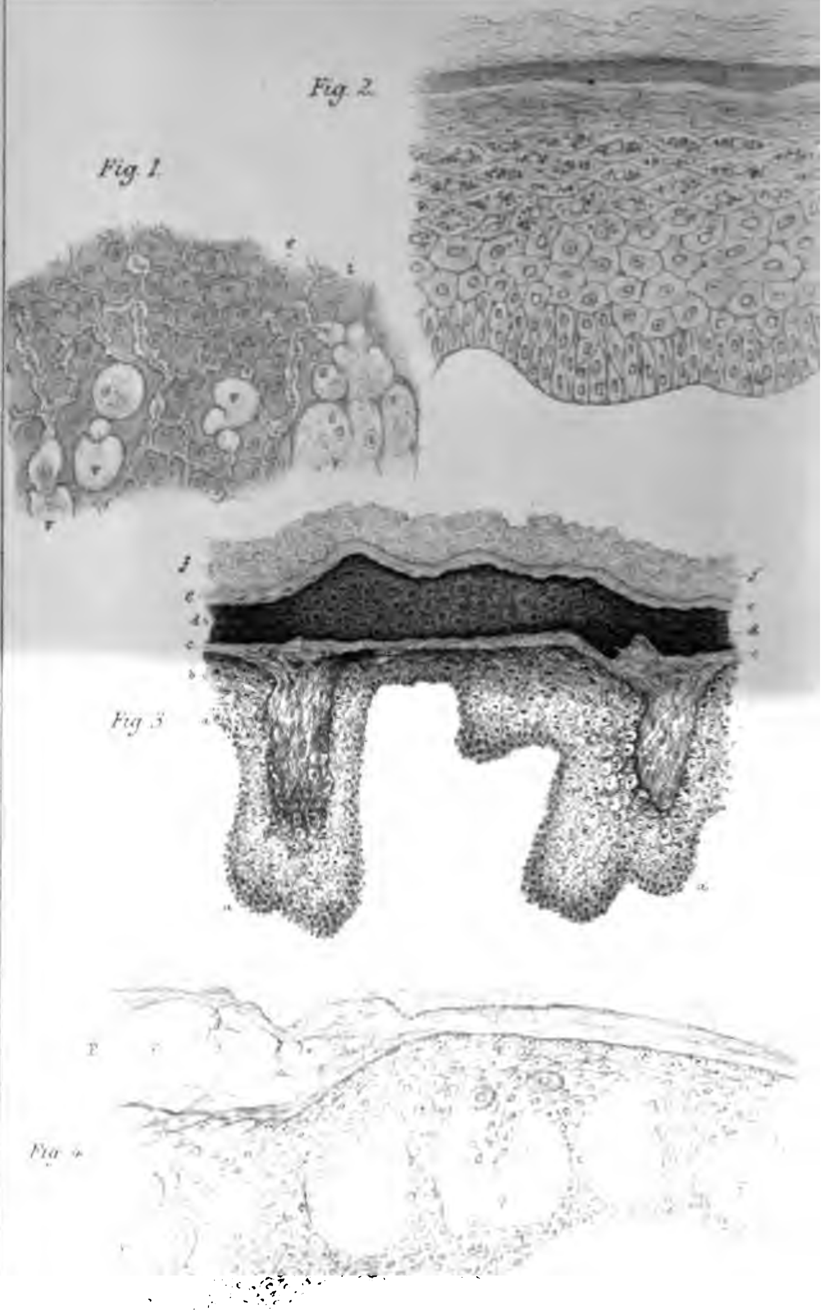


Fig. 3.

Fig. 4.

DESCRIPTION OF PLATE XXIII,

Illustrating Prof. Boettcher's Paper on the Structure of Red Blood-corpuscles.

FIGS. 1—6.—Red blood-corpuscles of man after treatment with a concentrated alcoholic solution of corrosive sublimate and staining with carmine.

The colouring of the drawings has been omitted.

FIG. 7.—Human blood-corpuscles from the body of a person who died from poisoning by corrosive sublimate.

FIG. 8.—Red blood-corpuscles of the camel, treated in the same manner as those in Figs. 1—6.

FIGS. 9 and 10.—Red blood-corpuscles of the frog after treatment with a concentrated alcoholic solution of corrosive sublimate. Examined in water.

FIG. 11.—Frog's blood-corpuscles treated in a similar manner, after staining with carmine.

A more exact explanation of the figures is given in the text.

EXPLANATION OF PLATE XXIV,

Illustrating Dr. E. Klein's Memoir on Epidermis of Sheep-pox.

FIG. 1.—From a vertical section through the rete Malpighii of pustule of sheep-pock.

v. Vesicles in the epidermis, containing a small amount of fibrinous material.
i. Intercellular paths distended; in it can be seen the "spikes" of the "ridge-and-furrow cells."
e. Epithelium cells of rete Malp. (Hart. III, 7).

FIG. 2.—Vertical section through the epidermis of sheep-pock.

a. Deep layers of cells of rete Malpighii.
b. Middle layers of rete Malpighii.
c. Layers of "granular cells."
d. Superficial layers of rete Malpighii.
e. Stratum lucidum.
f. Stratum corneum (Hart. III, 7).

FIG. 3.—From a transverse section through the central part of a (primary) pock, stained with carmine and hæmatoxylin.

a. Deep layer of rete Malpighii.
b. "Granular layer" of rete Malpighii.
c. Median horny streak or median stratum lucidum.
d. Superficial portion of rete Malpighii.
e. True stratum lucidum.
f. Stratum corneum (III, 5).

FIG. 4.—Vertical section through the epidermis of sheep-pock.

a. Deep layers of cells of rete Malpighii.
v. Vesicles formed in the middle layers of rete Malpighii.
b. Layers of "granular cells."
c. Stratum lucidum.
d. Stratum corneum.

P is near the periphery, the other end of the drawing near the centre of the pustule (II, 5).

EXPLANATION OF PLATE XXV,

Illustrating Professor Lankester's "Notes on Embryology and Classification."

A. Anus.
Ar. Architroch.
Br. Branchiotroch.
Ce. Cephalotroch.
Ep. Epitroch.
F. Foot.
G. F. Gill-filaments.
Lb. Labial tentacles.
M. Mouth.
Shg. Shell-gland.

The dotted band represents the cephalic, the black band the branchial portion of the architroch.

FIG. 1.—Hypothetical telostomiate organism, with primitive axis and circular architroch. *Ar.*

FIG. 2.—Hypothetical prostomiate organism, with secondary axis and shifted architroch. *Ar.*

FIG. 3.—Architrochic Echinoderm larva (after Gegenbaur).

FIG. 4.—Zygotrochic Echinoderm larva (after Gegenbaur).

FIG. 5.—Front view of zygotrochic Echinoderm larva.

FIG. 6.—Cephalotrochic larva (of Chætopod, Nemertine, or Gastropod Mollusc), the so-called "Trochosphere."

FIG. 7.—"Pluteus" larva of Echinids and Ophiurids (architrochic, anepitrochic).

FIG. 8.—"Tornaria" larva of Balanoglossus (zygotrochic, epitrochic).

FIG. 9.—"Auricularia" larva of Holothurian (architrochic, anepitrochic).

FIG. 10.—Transition form of the architrochic Auricularia, leading to the "vermiform" larva.

FIG. 11.—Vermiform Holothurian larva (zygotrochic, polyepitrochic).

FIG. 12.—"Brachiolaria" larva of Asterids (zygotrochic, anepitrochic).

FIG. 13.—"Actinotrocha" larva of the Gephyræan Phoronis (architrochic, epitrochic, with deficient development of the cephalic portion of the architroch).

FIG. 14.—Lateral view of the same larva.

FIG. 15.—"Veliger" larva of Gasteropod, with filamentary cephalotroch comparable to the tentacles of Polyzoa (cephalotrochic, anepitrochic).

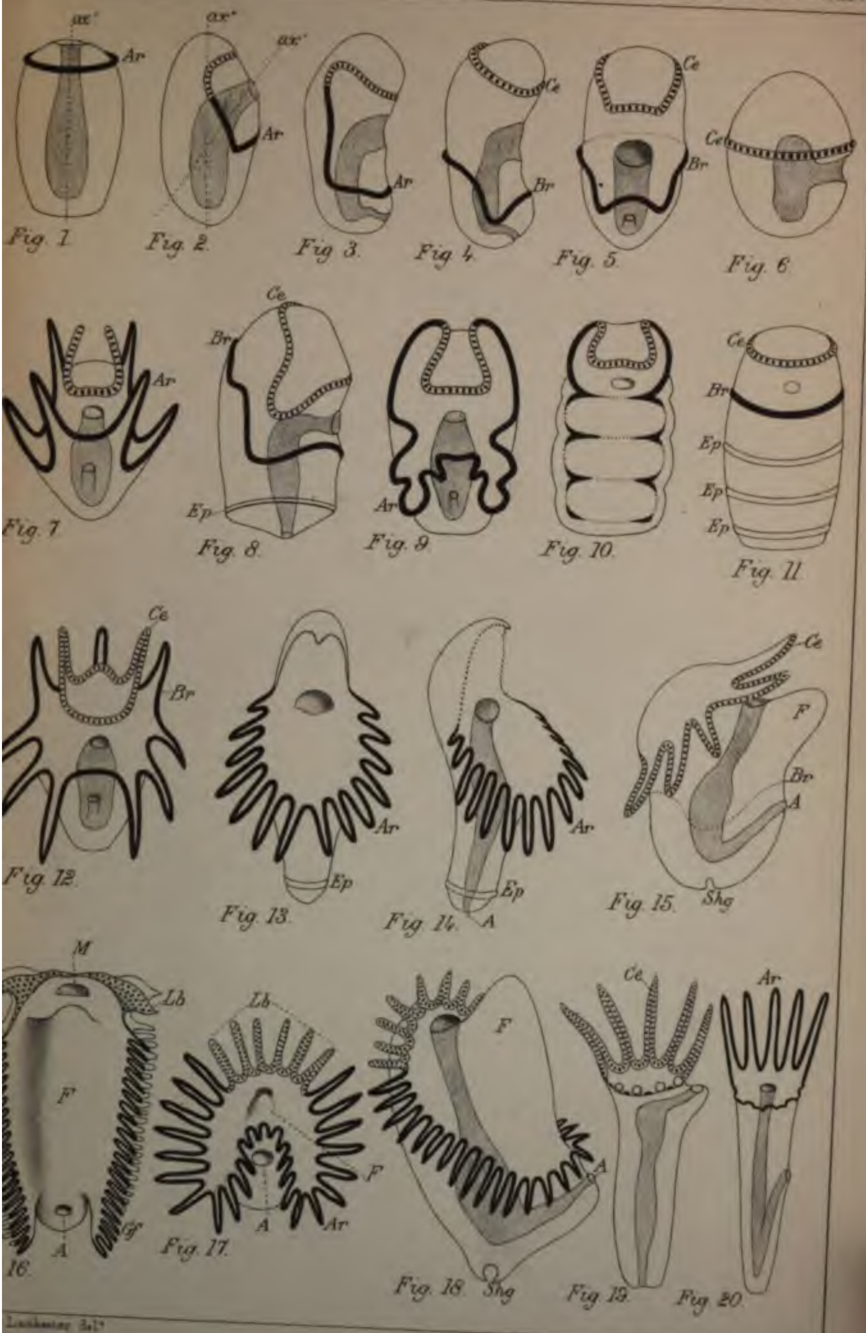
FIG. 16.—Diagram of a Lamellibranch Mollusc, seen from the ventral surface (architrochic, with conversion of the cephalic portion of the architroch into labial tentacles and of the branchial portion into gill-filaments).

FIG. 17.—Diagram of a Tentaculibranch Mollusc (Polyzoon), seen from the ventral surface (architrochic, anepitrochic).

FIG. 18.—Hypothetical mollusc with filamentous architroch, foot, and shell-gland.

FIG. 19.—Diagram of a Rotifer, with tentaculiferous cephalotroch.

FIG. 20.—Diagram of a Polyzoon, with circular tentaculiferous architroch.



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